Watershed Assessment of the Cottonwood and Whitewater Watersheds

Prepared for:

Malta Field Office,
Bureau of Land Management
Malta, Montana

By:

Linda Vance

Montana Natural Heritage Program
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EXECUTIVE SUMMARY

The Cottonwood and Whitewater 4th-code watersheds are located in Blaine and Phillips County, near the boundary of the Northern Great Plains prairie pothole region in north-central Montana. In 2003, the Montana Heritage Program completed an assessment of the Whitewater watershed (Crowe and Kudray 2003). Under agreement with the BLM, that work was extended to the Cottonwood watershed, and the original study data was reanalyzed and updated so that 5th-code watersheds within the two larger 4th-code watersheds (plus portions of the Middle Milk) could be compared.

The study area encompasses 1,139,021 acres, of which 4.7% (53,488 acres) are wetlands. Uplands comprise almost 95% of the watershed (1,085,533 acres). There are 1,286 miles of perennial and intermittent streams. Slightly over 40% of the study area is publicly owned or managed, with 78.6% of public land under BLM administration. Most of the land area is grassland, and both public and private grasslands are used primarily for cattle grazing. Approximately 35% of the study area is in agricultural use (hay, small grains, row crops, or fallow). Twenty-seven percent of the land within 100 meters of lentic wetlands and 9% of the land surrounding perennial and intermittent streams is in agriculture. Across the watershed, 46.1% of lacustrine wetland acres and 7.9% of palustrine wetland acres have been hydrologically modified. Slightly over 6% of palustrine wetlands in the study area are impounded.

Our methodology included both broad-scale GIS and fine-scale field assessments. The GIS analysis examined underlying diversity, measured current conditions, and evaluated potential threats. Field sampling included proper functioning condition determinations, intensive riparian assessments, and aquatic community inventories. In our GIS assessment, we characterized underlying diversity within 5th code watersheds on the basis of soil-based ecosites, topography, and wetland type/distribution. When the three measures of diversity were combined into a Composite Diversity Index, Woody Island Coulee ranked highest overall, and Buckley Creek lowest. To assess wetland and watershed condition, we gathered and analyzed data on land cover and land use, natural vegetation communities, land stewardship, water diversion, and wetland/riparian disturbance. We calculated a Composite Wetland Condition Index from seven sub-indices. Whitewater watershed had the highest condition ranking, and Murray Coulee the lowest. We then used a Composite Wetland Threat Index to evaluate ongoing threats from grazing and agriculture, and to assess the potential threats from agricultural conversion and protracted drought. For most of the watersheds, grazing and drought were the major threats. Murray Coulee and Sneider Coulee watersheds were the most threatened of the 5th-code HUCs.

Several key facts emerged from the GIS data analysis:

- Based on cadastral data and allotment boundaries, between 81% and 98% of the land in natural cover is grazed.
- Comparisons between expected natural communities and current land cover indicate that the greatest loss of community type has occurred in shrub/evergreen communities.
- More than a third of the wetlands across the study area have some direct disturbance as a result of hydrological alteration or stockwatering activities.
- Surface water is a highly manipulated resource throughout the study area, and free-flowing channels are probably rare. In the Whitewater watershed, for example, there are over 27 dams and diversions per mile of perennial and intermittent stream.
- Fifty percent or more of the streams in every watershed except Black Coulee are within 50 meters of a road.

As part of the fine-scale assessment, we surveyed 161 potholes and wetlands across the study area. PFC assessments were done at 97 sites (some sites had more than one pothole). Of the 97 sites surveyed, 30, or 31%, were considered to be functioning at risk. We also carried out intensive

riparian assessments at 17 sites and calculated an overall Floristic Quality Index, the percentage of non-native species, the total percentage of species that are tolerant to disturbance, and the percentage of species that are intolerant to disturbance. Almost all sites exhibited a high percentage of disturbance-tolerant species, with values as high as 0.0% to 69.4% for woody species, and 68.2% for herbaceous species. Non-native herbaceous species were common throughout the riparian area.

During our aquatic condition inventories, we found that most of the unconnected streams were dry, and many 2nd order streams contained no water or only interrupted pools. The mainstem of Cottonwood Creek is severely incised and continually downgrading its channel, and contains few of the expected fish species for a stream this size. Woody Island Coulee contained the most intact fish community, and has many stream reaches with high biological integrity. Assiniboine Creek (in Stinky Creek watershed) had a full complement of expected species.

We did not find clear relationships between the broad-scale and fine-scale assessments. Broad-scale assessments look at impacts, i.e. the activities and events that change natural conditions, while fine-scale assessments examine the results of those impacts. Impacts may occur at a significance distance from their effects. Localized impacts may also override watershed-level ones. In our visits to wetlands in the study area, we observed that the most significant effects on plant community composition and proper functioning condition corresponded to local impacts of grazing and/or hydrologic alteration. The value of watershed-level assessments lies in identifying areas where impacts are currently occurring, rather than merely seeking out effects that have already occurred.

Based on both levels of assessment, we identified several management opportunities that would support wetland and watershed health:

- Placement of stockwatering tanks, nutrient feeders and salt blocks in places with a low concentration of wetlands; exploration of rotational grazing to protect breeding waterfowl in spring and to limit trampling of potholes in late summer; increased range condition monitoring; and protection of high quality wetlands with physical barriers.
- Avoiding direct encroachments by oil and gas pipelines in wetlands, and planning associated roads to minimize impacts from dust, traffic, and erosion.
- Continuing to monitor for noxious weeds. The study area is unusually free of noxious weeds.
- Management of lands around Woody Island Coulee to protect the aquatic resource.

In general, the study area has not suffered the same level of impacts as many parts of the Northern Great Plains Prairie Pothole Region, and a high percentage of its wetlands are still functioning and intact. However, increased oil and gas development, drought, overgrazing and noxious weeds all represent significant threats.

Acknowledgments

This project was supported by an assistance agreement with the Bureau of Land Management. I thank Marc Jones and Drake Barton for their work on the intensive riparian assessment, and Dave Stagliano for the results of his aquatic inventory. I also thank Greg Kudray and Sue Crispin for reviewing and proofreading this report in its various stages, and Coburn Currier for report formatting and production. Many people contributed to the work underlying this report, including Rich Adams, Elizabeth Crowe, Jon Kautt, Dennis Linghor, Amy Pearson and Jon Pierce, and I am grateful for their fine efforts. However, any errors of commission or omission are mine alone.

TABLE OF CONTENTS

List of Figures

List of Tables

INTRODUCTION

The study area encompasses all of the Cottonwood and Whitewater watersheds, and a portion of the Middle Milk watershed, all lying at the southwestern edge of the prairie pothole region (Figure 1), an area that is unique and significant on both a national and global scale (Weller 1981, Mitsch and Gosselink 1993). The Whitewater watershed is especially rich in prairie potholes, and the Whitewater wetlands complex have been recognized as a conservation target by The Nature Conservancy (1999). However, the entire area has a high concentration of these potholes, and the area as a whole represents a distinct and important Montana landscape.

Unlike many significant natural areas in the U.S., the prairie pothole region of Northern Montana is not the subject of any focused state or federal protection efforts. Land ownership in the Cottonwood watershed is primarily private, with land use divided between cattle grazing on native prairie, and small grain, row crop, and hay production. Federal and state ownership is scattered throughout the watershed, and public lands are generally leased for grazing. The Black Coulee National Wildlife Refuge encompasses 1,494 acres in the southwestern portion of the watershed. By contrast, in the Whitewater watershed, land ownership is predominantly federal, and managed by the Bureau of Land Management (BLM), although there is also substantial private land and several state sections. Here, most of the land is still in native prairie, with both private and public land used for cattle grazing. For the most part, the remaining land is either fallow or used for small-grain cropping.

An earlier report (Crowe and Kudray 2003) assessed the extent and condition of the Whitewater watershed prairie pothole wetlands, combining field sampling with a broad-scale GIS analysis. This report extends that investigation in three ways: first, by including the wetlands of the adjacent Cottonwood watershed and portions of the Middle Milk watershed; second, by broadening the scope of the assessment; and third, by using smaller subwatersheds (USGS 5th code hydrologic units, or HUCs) as the unit of analysis. It also includes newly developed indices of watershed integrity and threat assessment. The approach in this phase of the study included sampling both pothole and riparian sites, using a range of field sampling techniques to assess wetland health. Field sampling results were then integrated into a GIS analysis to provide a comprehensive evaluation of landscape condition and health in both the Cottonwood and Whitewater watersheds.

Figure 1. Extent of Prairie Pothole Region in North America (from Euliss et al. 2002; used by permission of authors)

The Ecological Setting: Climate, Geology, Landform, Soils, and Hydrology

The study area watersheds (Figure 2) are within the Northwestern Glaciated Plains Ecological Section (McNab and Avers 1994), where rolling hills and level to gently rolling glacial till plains are underlain by soft marine shale. Fire and drought are the primary sources of natural disturbance; land use is primarily cropland and grazing (McNab and Avers 1994).

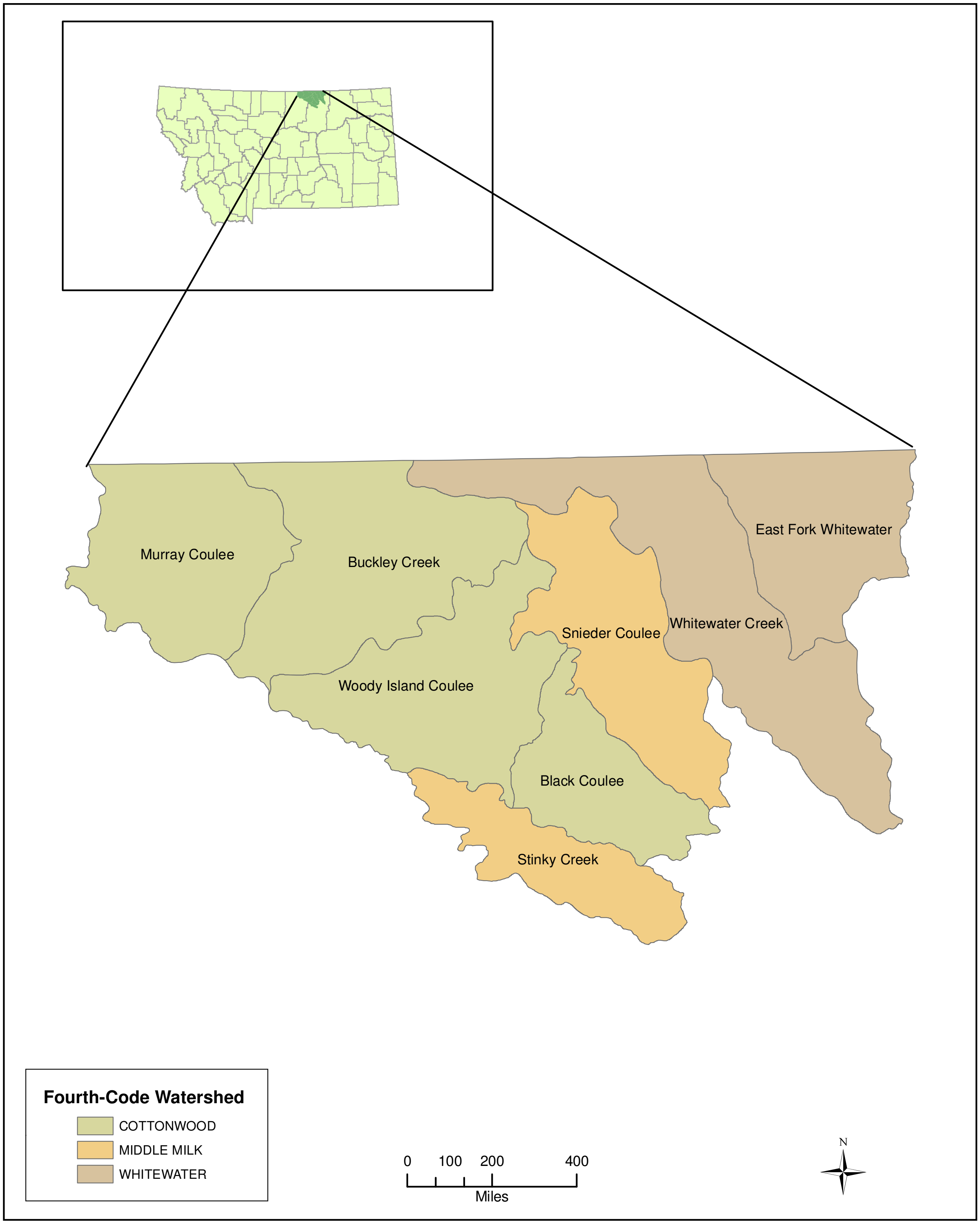


Figure 2. Location of study area, Blaine and Phillips Counties, Montana

Climate

Northeastern Montana has a relatively cool and dry climate. Records maintained by the Western Regional Climate Center (2003) provide summary statistics for parts of the study area. Average yearly maximum temperatures range from 55.3°F at Turner, in Blaine County, to 53.2°F at Whitewater, in Phillips County, while average minimum temperatures are 29.6°F and 24.8°F, respectively. July and August are the hottest months, with average maxima of 82°F and 83°F at Turner, and 84.8°F and 85°F at Whitewater. Average annual precipitation in Turner is 12.17 inches; at Whitewater, the average is 10.67 inches. Across the entire study area, average annual precipitation ranges from 12 to 15 inches, with the wettest areas occurring in the westernmost part of Murray Coulee watershed (15 inches) and the easternmost portion of the East Fork Whitewater watershed (14 inches). Snowfall during winter months is higher in the western part of the study area, averaging 25 inches a year at Turner but only 20 inches a year in Whitewater. In general, both snowfall and average annual precipitation are lower than in other parts of the broad prairie pothole region to the north and east.

Geology, Landform and Soils

During the Cretaceous period, 136-65 million years ago, the Western Interior Seaway split North America in two, covering all of Montana east of the newly formed Rocky Mountains (Zimmerman 1968). Fine textured silts, eroded from the mountains, consolidated in what were low-lying areas to form shales, while heavier sands were deposited closer to shore, where marshy vegetation

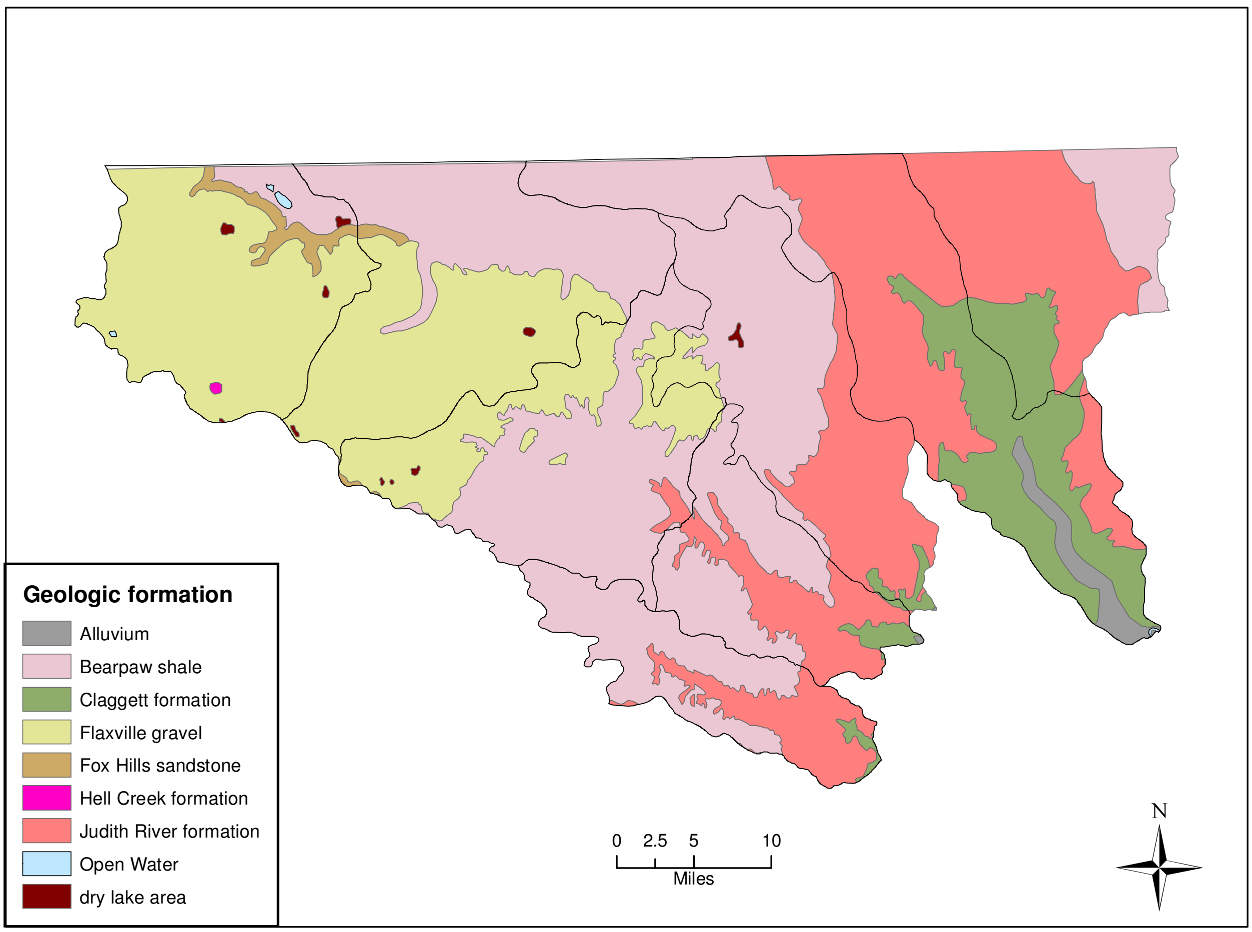


Figure 3. Major geological formations in study area

flourished. Three of the four major formations in the study area date from this period (Figure 3).

The Claggett Formation, a dark gray shale and siltstone, underlies the entire area, reaching a depth of 500 feet. It forms the major layer only in low-lying parts of the study area, primarily in the lower reaches of the Whitewater and East Fork Whitewater watersheds (Hilts 1986).

The Judith Formation, as deep as 550 feet in some places, is laced with thin coal beds, derived from the Cretaceous marshlands. It dominates the eastern third of the watershed in a band that extends from the Saskatchewan border down through most of the Whitewater Creek watershed and the western part of the East Fork Whitewater watershed, and into the Sneider Coulee, Black Coulee, and Stinky Creek watersheds.

The Bearpaw Formation, up to 1,100 feet thick in some areas, is a dark gray marine shale overlying the Judith Formation. It is exposed primarily in the eastern third of the East Fork Whitewater Creek watershed, and through the central portion of the study area (Figure 3). Two thinner formations overlie these thicker ones: the Fox Hills Formation, a brown sandstone, and the Hell Creek Formation, an interbedded sandstone and shale that outcrops only in limited areas in the western part of the study area.

The fourth major formation in the study area is of more recent origin. The Flaxville Gravels are remnants of alluvial terrace deposits dating from 10 to 0.1 million years ago. This sand and gravel formation is an unconsolidated mix of rounded quartzite and argillite in a sandy matrix. These gravels, much less erodible than the Bearpaw shales, were deposited across a 100,000+ acre plateau in Murray, Buckley, and Woody Island Coulees, known locally as the Big Flat. The formation is a highly productive aquifer (Zimmerman 1960), and it is not uncommon to see springs, seeps, and woody draws along the edges of the formation, where water carved deep, wide trenches in the adjoining sandstones and shales during the erosional period that followed the deposition of these gravels (Figure 4).

Figure 4. Seep at edge of Flaxville Gravel Formation, Woody Island Coulee

Between 130,000 and 15,000 years ago, at the end of the Tertiary period, glacial tills were deposited with the advance and retreat of the ice sheets. Because the rocks caught in the ice were not evenly distributed, and because ice melted at different rates as the glaciers retreated, the glacial till formed the rolling hills and depressions that characterize the prairie pothole landscape today (Hilts 1986). The irregular surface has impeded the establishment of drainage channels, and so the fine silts and clays eroded from the till are deposited in the depressions. Glacial retreat also left behind melt-water channels, and these channels, along with the new channels carved out by the Milk River tributaries, carried alluvium downstream. Significant deposits can be seen in the lower part of the Whitewater Creek drainage.

Glacial deposits have produced a variety of soils in the study area watersheds in both Blaine and Phillips Counties. Glacial streambeds and outwash produced gravel and stone deposits in some areas, while silt and clay loams are the dominant textural matrix in others (Smith 1968). Table 1 shows the broad soil-based ecosite types and their distribution across the individual 5th-code HUCs. These soil-based ecosites in turn determine the extent and type of natural communities that dominate the region and shape patterns of agricultural use.

Hydrology

Wetland landform, soils, and vegetation are closely linked to the hydrology of local and upland environments. This is especially true in the prairie pothole region, where poorly defined or non-existent surface drainage channels are a characteristic of the rolling landscape. Fine-textured, low-permeability soils limit infiltration (Winter 1989), and small drainage basins concentrate even the small amount of surface runoff. Rainfall accumulates rapidly in potholes during spring months, especially when soil frost is sufficiently deep to forestall all infiltration until after the ground thaws. With frozen ground producing virtually impermeable soils, springtime rains and runoff will produce far higher surface water levels than summer rain and runoff events (Winter 1989). Evapotranspiration is the probable primary conduit for water loss (Shjeflo 1968). In Montana's semi-arid climate, evapotranspiration will generally be much greater than precipitation during summer months. Moreover, the same clay and silt soils that limit infiltration when wet are prone to developing secondary cracks during dry months, resulting in rapid infiltration when summer rain events occur. Consequently, prairie potholes will be relatively dry throughout most years, and only hold measurable amounts of water in years when precipitation significantly exceeds average. In short, prairie potholes are highly dependent on the vagaries of weather, and extreme variability is the norm.

Although precipitation and evapotranspiration are the principal drivers of water exchange in prairie potholes, both subsurface and surface interactions can occur between individual wetlands. Subsurface flows are well-documented (reviewed by Winter 1989), and permit water retention over significant periods of time, far exceeding what would be expected if only surface inputs and evaporation are considered (Winter and Rosenberry 1995). Depending on the underlying geology and hydraulic head, individual wetlands can be recharge wetlands, discharge wetlands, or flow-through wetlands; topographic position alone is insufficient as an indicator of pothole hydrology (Leibowitz and Vining 2003). Flows can also reverse on a seasonal basis: an individual pothole can be a discharge wetland in the spring, receiving ground water from uplands, then become a recharge wetland in summer as evapotranspiration creates a groundwater sink (Winter 1989).

Surface connectivity occurs among some prairie potholes, with topographically lower wetlands receiving inputs from upslope wetlands (Sloan 1972, Labaugh 1989, Winter 1989, Rosenberry and Winter 1997, Winter and Rosenberry 1998). In certain areas, surface water connections may occur sporadically when periods of intense rain result in potholes overflowing and forming temporary connections to adjacent ones. Leibowitz and Vining (2003) have coined the term "temporal connectivity" to refer to this phenomenon, and suggest that it be considered not as a presence-absence occurrence, but rather as "a probability

Table 1. Soil-based ecosites across the study area (from SSURGO database, NRCS)

Ecosite classification	Whole	Black Coulee	Buckley Creek	EastFork Whitewater	Murray Coulee	Sneider Coulee	Stinky Creek	Whitewater	Woody Isl. Coulee
Clay pan, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x		x	x	x	x
Clayey, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x	x	x	x	x	x
Clayey, 10 to 14 inch Ppt zone, sedimentary plains, central	x	x	x	x		x	x	x	x
Coarse clay, 10 to 14 inch Ppt zone, sedimentary plains, central	x								x
Dense clay, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x	x	x	x	x	x
Dense clay, 10 to 14 inch Ppt zone, sedimentary plains, central	x		x		x				x
Overflow, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x		x	x	x	x
Overflow, 15 to 19 inch Ppt zone, northern Rocky Mountain foothills, central	x		x		x			x	x
Saline lowland, 10 to 14 inch Ppt zone, glaciated plains, central	x		x	x	x			x	x
Saline upland, 10 to 14 inch Ppt zone, glaciated plains, central	x		x	x	x		x	x	x
Saline upland, 10 to 14 inch Ppt zone, sedimentary plains, central	x				x				
Sandy, 10 to 14 inch Ppt zone, glaciated plains, central	x		x	x	x	x	x	x	x
Shallow clay, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x			x		x
Shallow clay, 10 to 14 inch Ppt zone, sedimentary plains, central	x	x		x		x		x	x
Shallow clay, 10 to 14 inch Ppt zone, sedimentary plains, east	x	x				x	x	x	x
Shallow to gravel, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x		x			x
Shallow to gravel, 15 to 19 inch Ppt zone, northern Rocky Mountain foothills, central	x		x		x				x
Shallow, 10 to 14 inch Ppt zone, glaciated plains, central	x	x		x		x	x	x	x
Shallow, 10 to 14 inch Ppt zone, sedimentary plains, central	x				x				
Shallow, 10 to 14 inch Ppt zone, sedimentary plains, east	x	x				x			
Shallow, 15 to 19 inch Ppt zone, northern Rocky Mountain foothills, central	x								x
Silty, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x	x	x	x	x	x
Silty, 10 to 14 inch Ppt zone, sedimentary plains, central	x		x		x				x
Subirrigated, 10 to 14 inch Ppt zone, glaciated plains, central	x		x			x		x	
Thin clayey, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x	x	x	x	x	x
Thin clayey, 10 to 14 inch Ppt zone, sedimentary plains, central	x	x		x		x	x		x
Thin silty, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x	x	x	x	x	x	x
Wet meadow, 10 to 14 inch Ppt zone, glaciated plains, central	x	x	x		x	x		x	x

event with some distribution over time and space." However, they note that temporal connectivity is much more likely to exist in the eastern part of the prairie pothole region, which is characterized by relatively flat terrain and higher precipitation. In the more rolling prairie landscapes and semiarid climate of the study area, the probability of this temporal surface water connectivity is likely to be distributed over fewer wetlands and a longer period of time. When surface water connections occur, however, they can have an ecologically controlling effect. Surface water flow from larger, upslope wetlands can increase electrical conductivity and salinity (Leibowitz and Vining 2003), both of which are factors controlling the distribution of plants (Stewart and Kantrud 1971) and invertebrates (Euliss et al. 1999) in prairie potholes.

The hydrologic functions at a given wetland can be determined in the field by salinity, or can be identified by vegetation types, which can also be remotely sensed by color infrared or satellite imagery. Potholes with high salinity tend to be groundwater discharge wetlands (Euliss et al. 1999). Potholes that are classified as temporarily flooded in the NWI mapping tend to recharge groundwater, while those characterized as seasonally flooded are generally either flow-through or groundwater recharge. Semi-permanently flooded potholes can have either groundwater discharge or flow-through functions (Euliss et al. 1999).

Natural Communities

The earlier Whitewater Watershed report (Crowe and Kudray 2003) described the natural communities of prairie potholes, and the classification of wetland habitat and vegetation. Those portions of the report are reproduced here in their entirety:

"Prairie potholes are well recognized for their value as critical breeding habitat for waterfowl but numerous other species also depend on this habitat. Invertebrates are critical food chain support for many species of birds and a wide variety of other organisms in addition to affecting nutrient dynamics, sediment chemistry and wetland productivity (Euliss et al. 1999). Invertebrates have adapted to the wet/dry cycles in potholes forming communities that become more diverse with increased water permanence (Euliss et al. 1999). They form the main food source and are the critical source of nutrients for breeding waterfowl. Invertebrates are influenced not only by water level fluctuations but also by climatic conditions, vegetation and anthropogenic disturbances like sedimentation (Euliss et al. 1999).

Prairie potholes also provide important habitat for many amphibians. Frogs, toads, turtles and salamanders are all dependent on water in potholes for all or part of their life cycle. Some of these species are "of concern" for Montana such as the Northern Leopard Frog (*Rana pipiens*), Plains Spadefoot (*Spea bombifrons*), and Great Plains Toad (*Bufo cognatus*). The Western Hognose Snake (*Heterodon nasicus*), although not directly dependent on wetlands, feeds on toads, which are dependent on standing water for at least part of their lifecycle. Species "of concern" have particular threats, declining population trends, or restricted distribution that warrant special attention.

Prairie potholes are also important for a number of bird species. They are considered to be the most important breeding habitat for waterfowl in North America with production estimates ranging from 50% to 80% of the continent's main species (Batt et al. 1989). However, the extreme variability in climate and thereby pothole water levels also results in extreme population fluctuations in waterfowl populations. In addition to waterfowl, prairie wetland support a diverse assemblage of water dependent birds including Montana species of concern such as the Black-crowned Night Heron (*Nycticorax nycticorax*), White-faced Ibis (*Plegadis chihi*), Franklin's Gull (*Larus pipixcan*), Common Tern (*Sterna hirundo*), Forster's Tern (*Sterna forsteri*), and Black Tern (*Chlidonias niger*). American White Pelicans (*Pelecanus erythrorhynchos*) feed extensively on tiger salamanders (*Ambystoma tigrinum*) found in prairie potholes.

The small mammal community in prairie wetlands in Montana is primarily composed of five species:

masked shrew (*Sorex cinereus*), muskrat (*Ondatra zibethicus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), deer mouse (*Peromyscus maniculatus*), and meadow vole (*Microtus pennsylvanicus*) (Fritzell 1989). Meadow voles have dramatic population cycles of around 3 – 5 years and are typically the most abundant small mammal. Small mammals are an important food source for many prairie predators. Dense grass cover is important in providing small mammal cover; the heavier vegetation cover natural to pothole wetlands may serve as a population reservoir if grazing is managed well. Since bats are obligate insectivores, they are probably influenced by the abundance of insects associated with potholes although their distribution may be more affected by the availability of suitable roosting sites.

Prairie potholes are also important habitat for larger mammals including red foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), mink (*Mustela vison*), weasels (*Mustela* spp.), striped skunks (*Mephitis mephitis*), and deer (*Odocoileus* spp.). Potholes represent both a source of food and cover. Predators like foxes and raccoons have a considerable effect on waterfowl breeding success; the spread of raccoons into the prairie has been regarded as a major influence in the marked decline of waterfowl nesting success over the last half century.

The amount and type of vegetation associated with potholes affect invertebrate habitat, hydrology, primary productivity, decomposition, and a wide variety of other ecological functions and human values. Pothole vegetation is used directly as food or habitat for many animals in the prairie including cattle. Although the potholes in this area are relatively dry compared to those found elsewhere, conditions support much more forage production than the surrounding uplands."

Prairie Pothole Wetland Habitat and Vegetation Classification

The flora of a prairie wetland depends on its water regime, salinity, and human disturbance (Kantrud et al. 1989). Specific vegetation communities often dominated by only one species can be recognized growing in the concentric zones of deeper pothole basins in correspondence to the water table depth and its persistence. Shallower basins may only have one or two vegetation zones but a zoned transition from low meadow vegetation to an aquatic community will occur in deeper basins. Salinity has a profound effect on pothole vegetation with decreasing numbers of species present as salinity increases (Kantrud et al. 1989). Human caused disturbance is widespread but varies in intensity and effect.

Potholes can be classified based on their habitats and/or their vegetation communities. Vegetation classification systems are based on dominant and characteristic plant species' composition and structure. These species groups serve as indicators of the environmental conditions, both regionally and site-specific, in which they occur. Habitat classification systems reflect the underlying gradients of hydrology and salinity that are strongly related to vegetation composition and may incorporate structural attributes of vegetation.

The National Vegetation Classification System (NVCS) (NatureServe 2002) has been adopted as the national standard for vegetation classification and is used by the Montana Natural Heritage Program (MTNHP). New vegetative associations, the finest level of detail in the NVCS, are still being described and refined in Montana by the MTNHP as needed. Plant associations are assigned ranks based on their conservation priority for a global and state basis. The NVCS has also identified a Northern Prairie Pothole Wetland Complex (see Appendix B for a complete description), which describes vegetative communities and environmental processes for the prairie pothole landscape mosaic.

There are two widely recognized wetland habitat classification systems by Stewart and Kantrud (1971) and Cowardin et al. (1979) that we can apply to the potholes in the Whitewater watershed. The National Wetland Inventory (NWI) uses the Cowardin et al. (1979) classification. Definitions of classification levels for these two habitat classifications are shown in Tables 1 and 2 in Appendix C.

Stewart and Kantrud (1971) characterized several wetland vegetation zones and the hydrologic phases typical of each zone. Each vegetation zone is also subdivided into one to several salinity subclasses.

Cowardin et al. (1979) developed a hierarchical classification with several levels based on amount of vegetation cover or substrate (where vegetation cover is less than 25%) and relative length of flooding during the year. They also used special modifiers to denote salinity and hydrologic modification.

ASSESSING WATERSHED HEALTH FROM A LANDSCAPE PERSPECTIVE

Lentic and lotic wetlands are not standalone systems, but are reliant on the flow of energy and materials from surrounding environments and are embedded in a matrix of vegetation, hydrology, soil composition, and human land use. Individual wetlands and streams receive inputs of chemicals, water and sediments from both their immediate surroundings and the upper watershed, and can be dramatically affected by withdrawals, diversions, and other hydrological modifications occurring at a significant distance. Similarly, most animal species depend both on specific habitats and their arrangement across the landscape, with overall species health requiring a number of appropriate habitats to ensure genetic exchange among populations, and to mitigate the impacts of site loss or degradation.

A watershed assessment should describe the past, the present, and future trends in ecological condition, incorporating information about factors of change that can have landscape-scale impacts on watershed health and integrity (Crowe and Kudray 2003). In this study, we used both broad-scale and fine-scale assessment approaches. Each has its strengths and limitations, but taken together, they complement each other, and provide different perspectives. We used a broad-scale approach to identify a number of changes in historic conditions, and to identify ongoing or potential threats to watershed health. In particular, we assessed land cover and land use across the broad landscape and in buffers around lentic and lotic wetlands, and evaluated modification and impacts within wetlands themselves. This allowed us to develop indices to assess conditions within single watersheds, and to compare conditions across the study area as a whole. The earlier Whitewater Report (Crowe and Kudray 2003) used this approach on a single 4^{th}-code Hydrological Unit (HUC); here, we use the approach to compare eight 5^{th} code HUCs. By expanding the scope of the assessment to a broader geographic area, and comparing a number of different watersheds within that area, we are able to take full advantage of a landscape perspective to evaluate watershed responses to environmental change.

The BLM's Proper Functioning Condition (PFC) method is a national fine-scale procedure for lentic and lotic wetlands (Pritchard et al. 1999). It uses field assessments of hydrology, soil, and vegetation to assign one of three functional ratings to individual wetlands: proper functioning condition, functional-at risk (with an upward, downward or non-apparent trend) or nonfunctional. We used this method in prairie potholes across the study area, and complemented this assessment with intensive riparian assessments and stream sampling at selected sites. Together, these landscape-level and site-specific assessments provide a wealth of information to support watershed management efforts.

METHODS

Broad-scale Remote Sensing Analysis of Wetlands

The broad-scale landscape assessment was designed to provide a landscape perspective on the natural diversity, current conditions, and potential threats within the entire study area and the 5th code HUCs. It was accomplished with a GIS analysis, using existing geographic and statistical data to derive summaries of potential and actual watershed condition, to develop indices that allowed comparisons of watersheds across the study areas, and to identify ongoing or future threats. Table 2 gives the name, source, basis and scale of the data used in this analysis.

The analysis was divided into three parts. The first part assessed the "background" or natural conditions in the watershed by describing potential natural communities, and by using standard indices of diversity to evaluate topography, wetland types, and soil-based ecosites. The second part addressed current conditions and disturbances, including land use, ownership patterns, and alterations and impacts to wetland and riparian areas. The third part focused on threats to wetland and riparian integrity, both actual (e.g. current grazing and agricultural impacts) and potential (ongoing drought, agricultural conversion). In each part, indices were created or used to facilitate comparison between subwatersheds, and to provide an overall assessment number for the study area as a whole

Table 2. GIS data layers used in remote sensing analysis

GIS Layer Name	Data Source	Remotely Sensed Imagery or Other Data Source Used; Date of Imagery Collection/Data Source Production	Useable Mapping Scale
National Wetlands Inventory	U.S. Fish and Wildlife Service, National Wetlands Inventory Program	1:24000 aerial photos: 1986	1:24000
National Land Cover Dataset	U.S. Geological Survey, Biological Resource Division	30m pixel Landsat Imagery; 1992	1:60000
Soil Survey Geographic	Natural Resource Conservation Service	National Soil Information System (NASIS) surveys	1:24000
Montana Water Rights	Montana Department of Natural Resources and Conservation, Water Resources Division 2003	Estimated from legal land descriptions or given geographical cordinates	variable
Montana Roads From TIGER 2003	U.S. Census Bureau Geography Division	U.S. Geological Survey 1:100000 base maps	1:100000
Montana Average Annual Precipitation 1961-1990	Oregon State University	PRISM-derived raster data and U.S. Geological Survey Digital Elevation Maps	1:100000
Montana Cadastral Database	Montana Department of Administration	Cadastral records; see http://gis.doa.state.mt.us for details	variable
Geology	Montana Bureau of Mines and Geology	Field surveys and mapping from 1944-1994	1:100000
National Hydrography Dataset	U.S. Geological Survey, Montana Natural Resource Information Service	U.S. Geological Survey 1:24000 topographic maps	1:100000
Montana 5th-Code Watersheds	U.S. Department of Agriculture, Natural Resources Conservation Service, Montana State Office	U.S. Geological Survey 1:100000 base maps; 1996	1:100000

and for the individual 5th code HUCs. This index-based approach follows a method initially developed by the Northeast Region of the National Wetland Inventory Program (Tiner et al. 2000), but modifies and expands it to address some of the unique conditions (e.g. grazing impacts, aridity, drought) in western ecosystems.

Geographic data used in the assessment and in calculating the sub-indices were derived as follows:

1. **Natural Diversity Index**
   a) **Ecosite Diversity Index**
      - Using the SSURGO database and 1:24,000 Soils map, create a layer of ecosites and sum acres within each ecosite class;
   b) **Topographic Diversity**
      - Create a topography polygon layer with 10-meter elevation intervals from USGS Digital Elevation Maps, and sum acreage in each elevation class;
   c) **Wetland Diversity Index**
      - From the NWI wetland layer, sum acres of each wetland class (e.g. Palustrine emergent seasonally flooded, Palustrine emergent temporarily flooded, Palustrine shrub-scrub, etc); for the purposes of this analysis, only unaltered wetland types were factored into the index;
2. **Composite Wetland Condition Index**
   a) **Natural Cover Index**
      - Sum the land cover categories within the watershed boundaries from the USGS National Land Cover Dataset and separated them into human and natural classes;
      - Make a public and private grazing lands layer by combining State Trust Lands and BLM lands with those privately held lands listed in the Cadastral database as having grazing as their primary use;
      - Overlay the natural land cover class on the public and private grazing lands layer, and summed the acreage within the overlay.
   b) **Natural Communities Index**
      - Using the SSURGO database and 1:24000 Soils map, build a layer of natural communities based on ecosites, and group communities into classes (e.g. shrub, grassland, deciduous forest) that correspond to natural land cover classes in the National Land Cover Dataset;
   c) **Stream Corridor Integrity Index**
      - Draw a 50- meter buffer on each side of stream segments in the 1:100,000 USGS National Hydrography Dataset streams layer;
      - Overlay the buffered stream segments on the National Land Cover Dataset;
      - Sum the acreage of land cover categories within the buffered areas.
   d) **Lentic Wetland Buffer Index**
      - Buffer all mapped lentic wetland polygons in the NWI wetland map by 100 meters;
      - Overlay the buffered wetland layer on the National Land Cover Dataset layer;
      - Sum the acreage of land cover categories within the buffered areas;
   e) **Wetland Direct Disturbance Index**
      - Group NWI polygons mapped as having hydrological alteration (diked, impounded, partially drained/ditched or excavated), and summed the acres in that class;
      - Create an unaltered wetlands layer from the NWI polygons;
      - Overlay the unaltered wetlands layer on the public and private grazing lands layer, and summed the acres of unaltered wetlands within grazed areas;
      - Build a stockwatering layer by extracting points of use listed as having stockwatering as their

primary use from the Montana Water Rights layer;
- Buffer the polygons in the unaltered wetlands layer by 10 meters;
- Overlay the stockwatering layer on the buffered unaltered wetlands layer, and identify those otherwise unaltered wetlands used for stockwatering or within 10 meters of stockwatering sites.

f) Diverted Stream Flowage Index
- Create a dams layer and a non-dam diversion layer from the Montana Water Rights layer
- Overlay the dams and non-dam diversion layers on the USGS National Hydrography Dataset 1:100,000 streams layer;
- Sum the number of dams or non-dam diversions that intersect streams;
- Sum the total number of stream miles.

g) Road Disturbance Index
- Buffer all mapped roads by 50 meters on each side;
- Sum acres of wetlands and miles of stream within the 100 meter road buffer zone.

3. Composite Wetland Threat Index

a) Wetland Grazing Threat Index
- Create a layer of natural land cover wetlands from all mapped NWI wetlands contained within the natural land cover classes from the National Land Cover Dataset;
- Overlay the public and private grazing lands layer on the natural land cover wetlands layer;
- Sum all natural land cover wetland acres (altered and unaltered) within public and private grazing lands layer;

b) Wetland Agricultural Threats Index
- Create a layer of agricultural land cover wetlands from all mapped NWI wetlands contained within agricultural land cover categories in the National Land Cover Dataset, and sum the wetlands within this new layer

c) Potential Agricultural Threat Index
- Create an agricultural land cover layer from the National Land Cover database;
- Overlay the agricultural land cover layer on the natural communities layer to identify the types of natural communities most susceptible to agricultural conversion;
- Identify the privately owned land currently in non-agricultural use within those natural communities;
- Select all parcels of 40 acres or more and create a potential agricultural lands layer. Sum acres of wetlands within that layer;

d) Drought Threat Index
- Join the NWI mapped wetlands to the Montana Average Annual Precipitation layer and assign a drought susceptibility rating to each wetland based on rainfall;
- Sum acres of wetland with each susceptibility rating.

Field Data Collection and Fine-scale Assessment of Wetlands

Data was collected in 2003, 2004 and 2005. In 2003 we completed 66 lentic wetland assessments in the Cottonwood watershed and 44 lentic assessments in an area of the Whitewater watershed that was not included in the initial Whitewater watershed assessment area. The assessments included a Proper Functioning Condition (Pritchard et al. 1999) evaluation, vegetation plot, photo, and site description.

In 2004, we conducted 17 intensive riparian assessments using methodology developed by the Montana Natural Heritage Program. These assessments were distributed on BLM land across all watersheds to evaluate the correspondence of landscape indices with intensive site data. Each assessment covered a reach extending 50 meters upstream and downstream from the sampling point. Twenty $0.1m^2$ quadrats were located along the greenline of each bank, and an additional three $0.1m^2$ quadrats were located along each of five perpendicular transects on each bank to determine presence and abundance of herbaceous species. Ten $4.0m^2$ plots were located along the greenline of each bank and one $4.0m^2$ plot was located on each transect to determine presence and abundance of woody species, as well as the extent of pugging, hummocking, and browsing. In all, 70 quadrats and 25 plots were placed at each of the 17 reaches.

In 2005, we completed 35 wetland assessments in an area of the Cottonwood watershed managed by the BLM's Lewiston Office. These assessments also included a Proper Functioning Condition (Pritchard et al. 1999) evaluation, vegetation plot, photo, and site description.

During all phases of data collection, wetlands were classified with the NWI (Cowardin et al. 1979) and Stewart and Kantrud (1971) systems. Vegetation communities were tentatively classified and correlated to these types. All plant taxonomy follows Kartesz (1999).

Results and Discussion

Broad-scale Assessment

Presettlement Condition

Prior to Euro-American settlement, the study area was primarily grassland grazed by native ungulates, particularly American bison (*Bos bison*), elk (*Cervus elaphus*) and pronghorn (*Antilocapra americana*). The intense short-term grazing regime of bison and elk influenced the structure, composition and production of vegetation. Even today, the plant species common in the grasslands that dominate the study area are well adapted to that regime. Figure 5, derived from soil and ecosite types, shows the natural community composition that probably characterized the area.

Indigenous human populations lived, hunted and traveled extensively through the watershed, taking advantage of seasonally changing natural resources. There is no indication of prehistoric drainage, excavation or impoundment of wetlands, rivers, or standing water, suggesting that prehistoric impacts on wetlands and riverine systems were minimal. However, beavers were abundant, building dams on narrow streams, which created broad low floodplains and perennial reaches.

Beginning in the mid 1800s, Euro-American settlers began moving into the southern part of Phillips County and establishing homesteads on which they farmed and ranched. Livestock production began in earnest in the 1880s, with thousands of cattle and sheep grazing the landscape. Malta was a principal shipping point for the Burlington Northern and

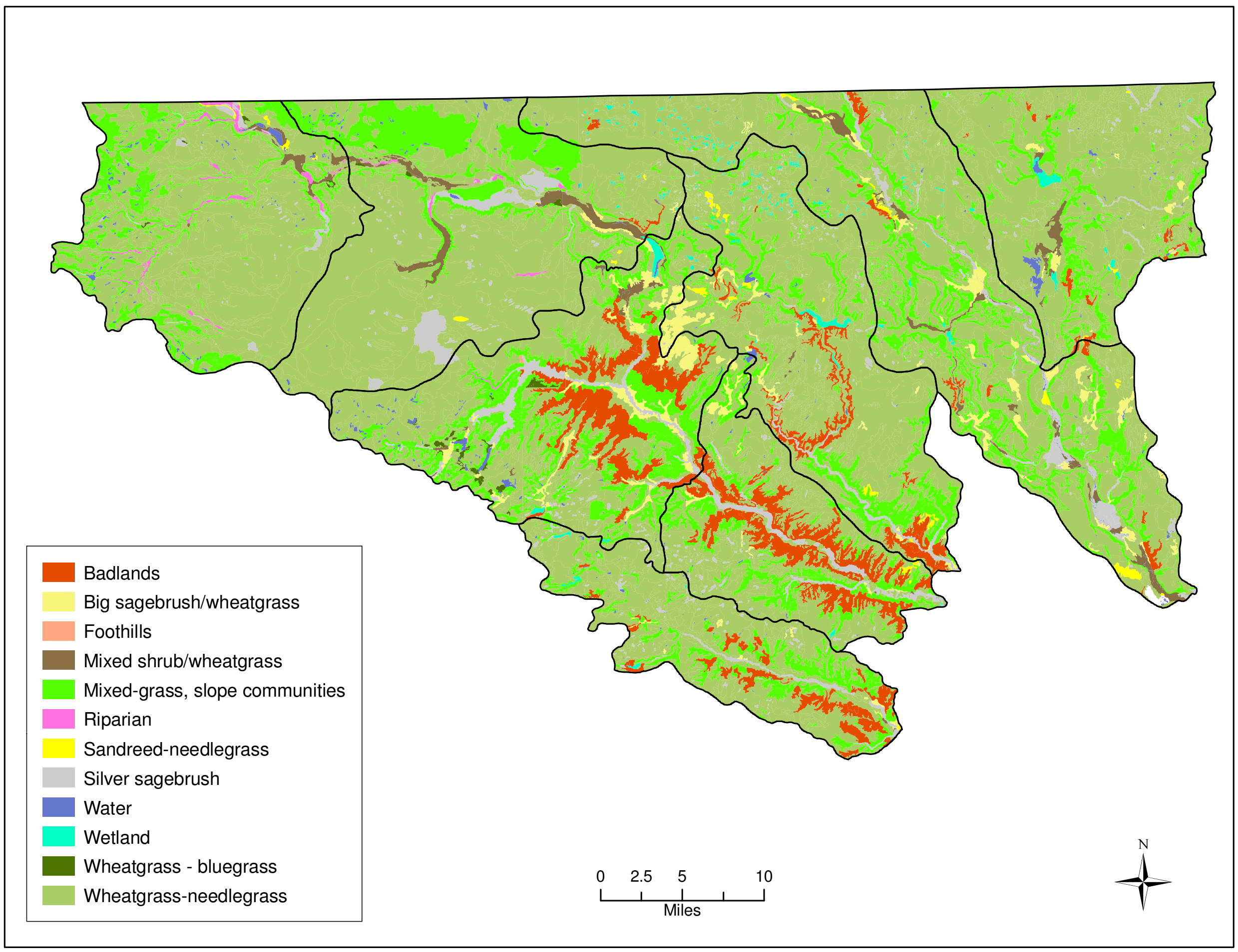


Figure 5. Natural community composition

Santa Fe Railroad, and by the turn of the century, the livestock industry was well established. (Bandy 2004). Blaine County was settled later, since most of the land was Indian reservation until 1887, when the Great Northern Railroad was completed. The county itself was established in 1912 (Montana Water Resources Board 1968). Dryland farming began in both counties in the early part of the 20th century, and the area was extensively homesteaded (Bandy 2004). Many of these farms failed, or were abandoned when irrigated land opened up elsewhere, and were bought back by the U.S. government under the Bankhead-Jones Act.

Table 3. Land stewardship in study area and 5th code HUCs

	Public Acreage	Total Acreage	Percent Public
Whole	464,754	1,139,021	40.8
Black Coulee	42,749	90,250	47.4
Buckley Creek	53,218	183,150	29.1
East Fork Whitewater	73,639	121,712	60.5
Murray Coulee	20,879	143,043	14.6
Sneider Coulee	51,037	143,930	35.5
Stinky Creek	24,588	80,888	30.4
Whitewater	118,555	217,424	54.5
Woody Island	80,088	158,624	50.5

Current Conditions

Slightly over 40% of the study area is publicly owned or managed (Figure 6), with the percentage in the 5th code HUCs ranging from a high of 60.5% in the East Fork Whitewater Creek watershed to a low of 14.6% in the Murray Coulee watershed (Table 3). Of the publicly managed land, 78.6% is under BLM administration, 14.5% is State Trust Land, and the remainder is administered either by the U.S. Fish and Wildlife Service (2.1%), Turtle Mountain Allotted Lands (4.7%) or Montana Fish, Wildlife and Parks (<1%). The majority of public land parcels are over 500 acres, but range from less than an acre to almost 120,000 acres. Black Coulee watershed has the highest percentage of public land patches with an area of 1000 acres or more, while Woody Island Coulee has the highest percentage of public land patches less than 50 acres in size (Table 4).

Most of the land area is still in native grassland cover (Figure 7 and 8a to 8h). Both public and private grasslands are used primarily for cattle grazing. Figure 9 shows the extent of land listed in cadastral records as having a primary use of grazing, or managed by the BLM or state trusts; since most BLM and state lands are leased for grazing, those areas are designated as "Public Grazing" in the map.

The study area encompasses 1,139,021 acres, of which 4.7% (53,488 acres) are wetlands (this acreage is calculated from NWI mapping, rather than from the NLCD). Uplands comprise almost 95% of the watershed (1,085,533 acres). There are 1,286 miles of perennial and intermittent streams. Of the wetland acreage, 3,312 acres are Lacustrine, 49,907 acres are Palustrine and 270 acres are Riverine (Figure 10). Figure 11 shows

Table 4. Size of publicly managed land patches, in percentage by whole study area and 5th code HUCs

	<50 acres	51-100 acres	100-500 acres	500-1000 acres	1000-10000 acres	10001-50000 acres	>50000 acres
Whole Area	15.4	7.3	39	29.5	7	1.1	0.6
Black Coulee	17.2	3.4	44.8	17.2	10.3	6.9	0
Buckley Creek	17.1	8.6	17.1	45.7	5.7	5.7	0
East Fork Whitewater	9.8	0	43.9	39	4.9	0	2.4
Murray Coulee	13.6	10.2	52.5	20.3	3.4	0	0
Sneider Coulee	8.6	4.3	51.4	27.1	7.1	1.4	0
Stinky Creek	6.5	38.7	35.5	12.9	3.2	3.2	0
Whitewater	14.5	13.3	38.6	21.7	10.8	1.2	0
Woody Island	30.2	9.4	22.6	24.5	11.3	1.9	0

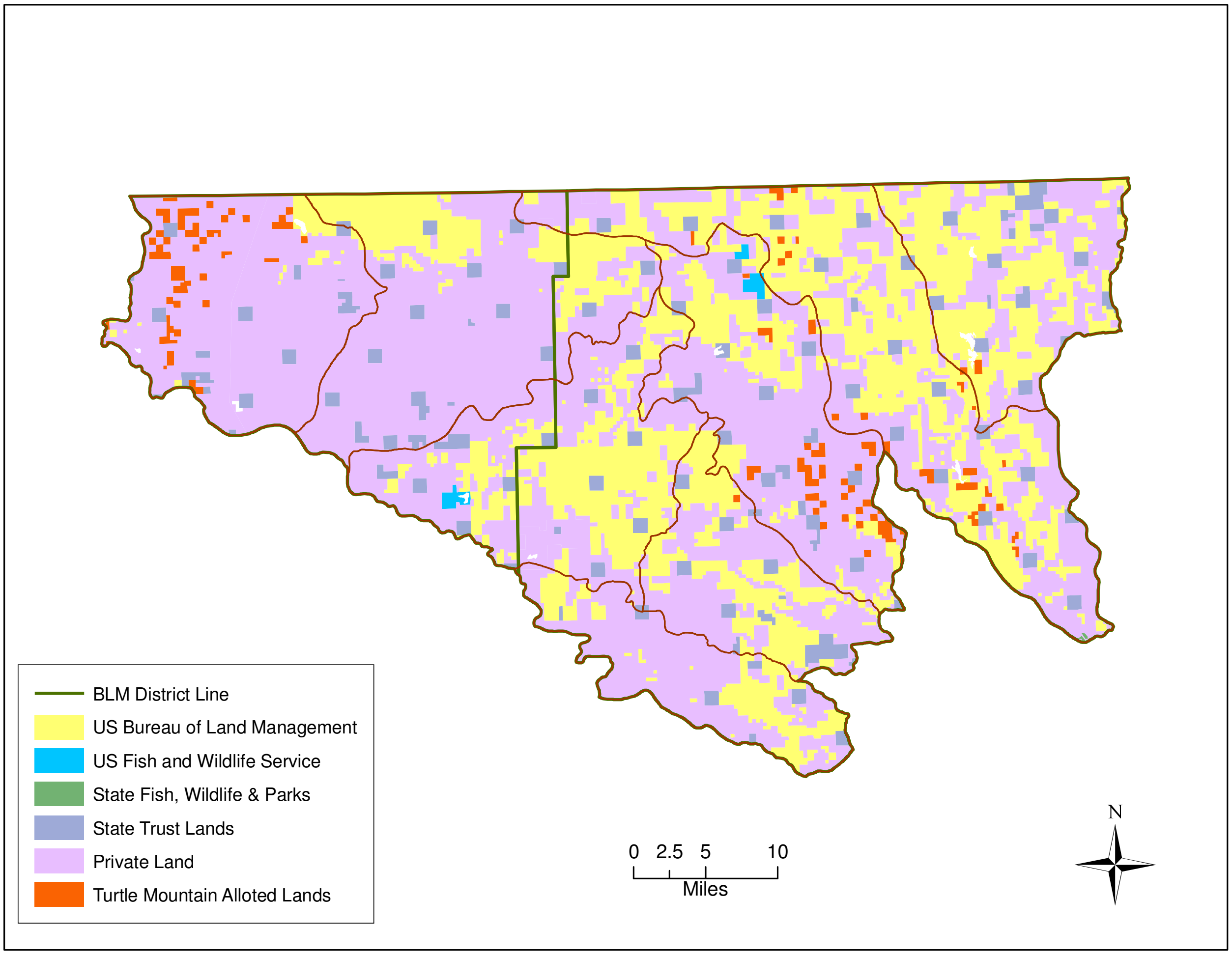


Figure 6. Land stewardship within the study area

the distribution of Palustrine wetland types across the study area. In the NWI mapping system, most prairie potholes are classified as Palustrine with emergent beds, and temporary, seasonal, or semi-permanent flood regimes. In the Stewart and Kantrud system, most are Fresh Wetland Low Prairie, Fresh or Slightly Brackish Wet-Meadow, or Fresh or Slightly Brackish Shallow-Emergent.

Factors and Magnitude of Wetland Change

Since Euro-american settlement began, and especially since agricultural expansion into the northern part of Phillips and Blaine counties, excavation and impoundment of potholes and stream reaches has been commonplace. One result of this has been an increase in number of aquatic bed and/or semi-permanently flooded Lacustrine and Palustrine wetlands. Table 5 shows the percentage of wetlands that have been physically altered (note that no riverine acres were mapped as altered). The percentages vary widely among 5th code HUCS, with some watersheds (e.g. Buckley Creek and Murray Coulee) having very little alteration, and others (Black Coulee, Stinky Creek) having a significant percent. This appears to be a function of size more than land use; Black Coulee and Stinky Creek have the smallest acreages of wetlands in the watershed, while Buckley and Murray rank first and third in acreage, respectively. Although it appears that no Riverine wetlands have seen modification, this is misleading; impounded streams are generally mapped as Lacustrine or Palustrine wetlands.

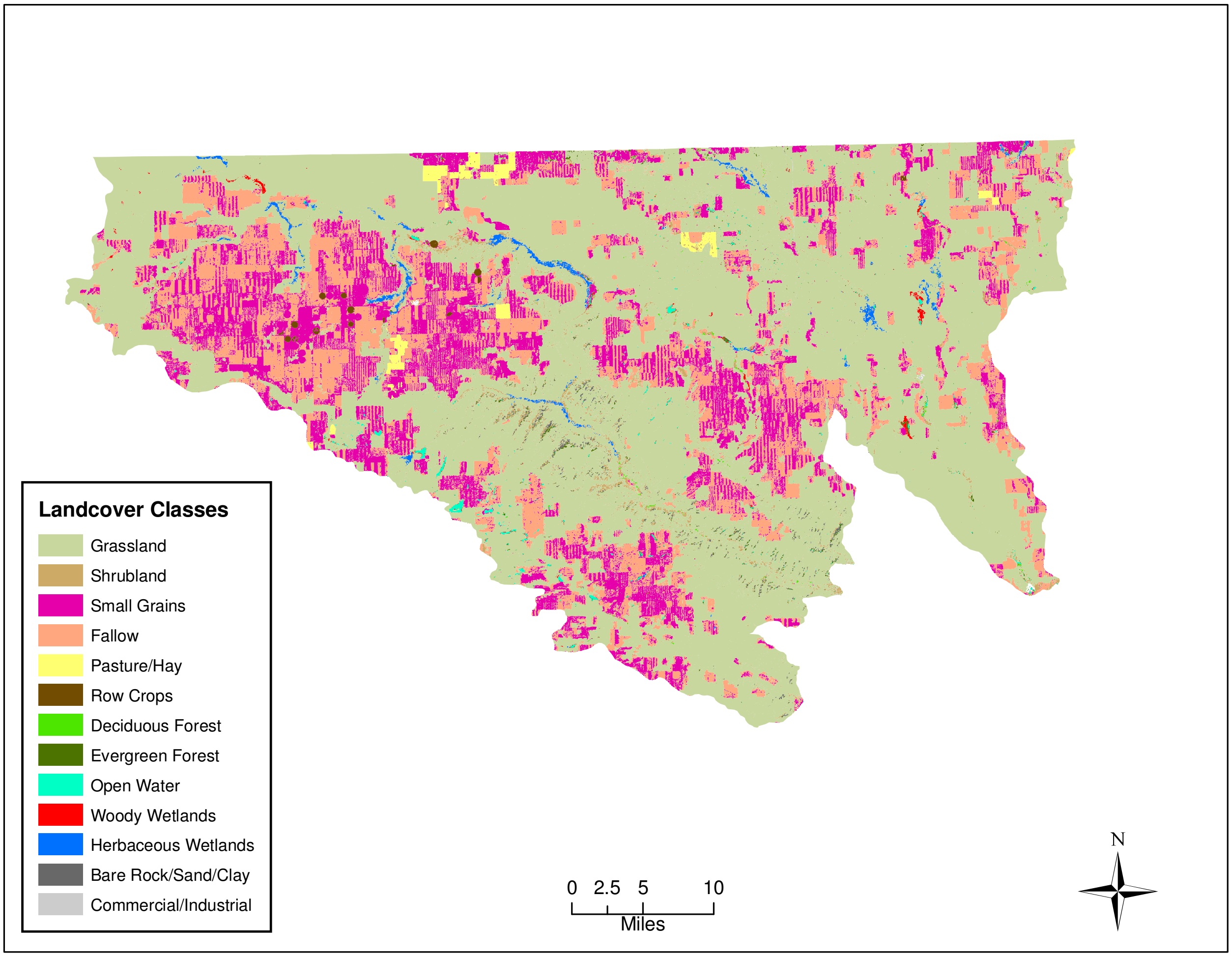
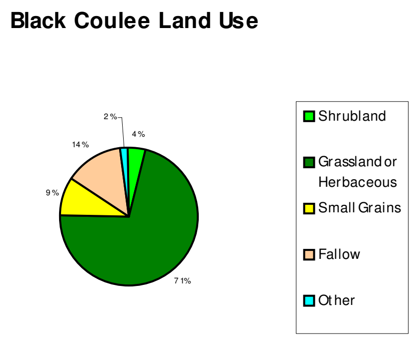
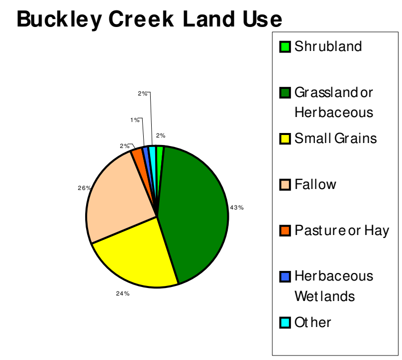
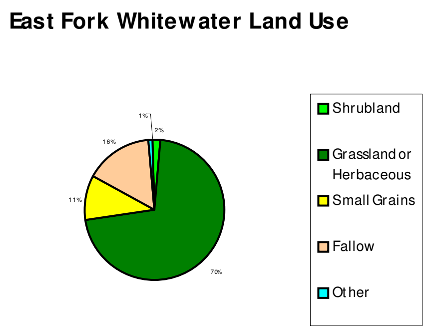
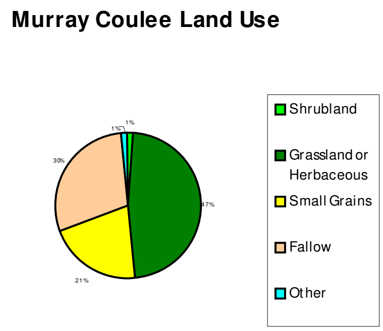


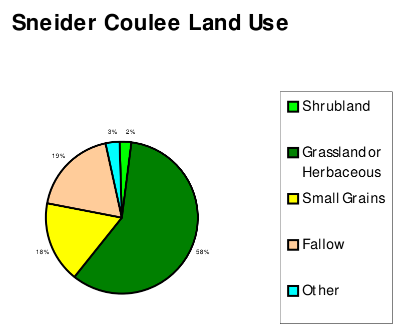
Figure 7. Land cover and human uses in the study area

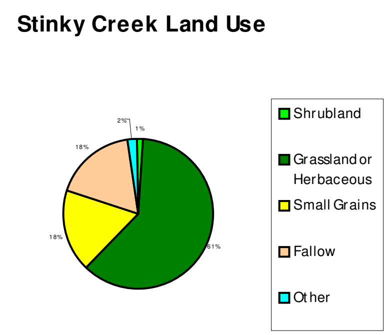


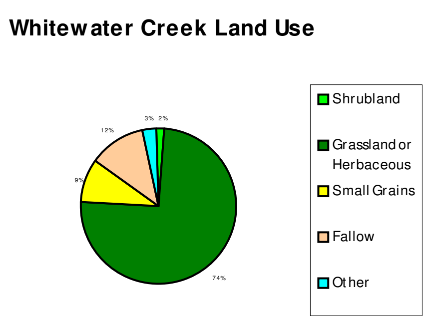


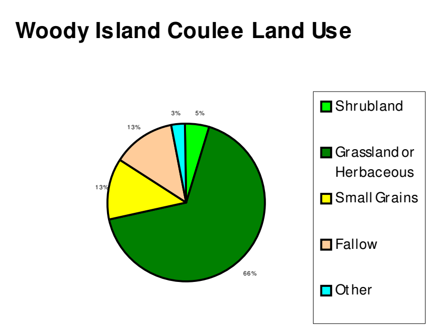












Figures 8a to 8h. Land cover and human land use, 5th code HUCs

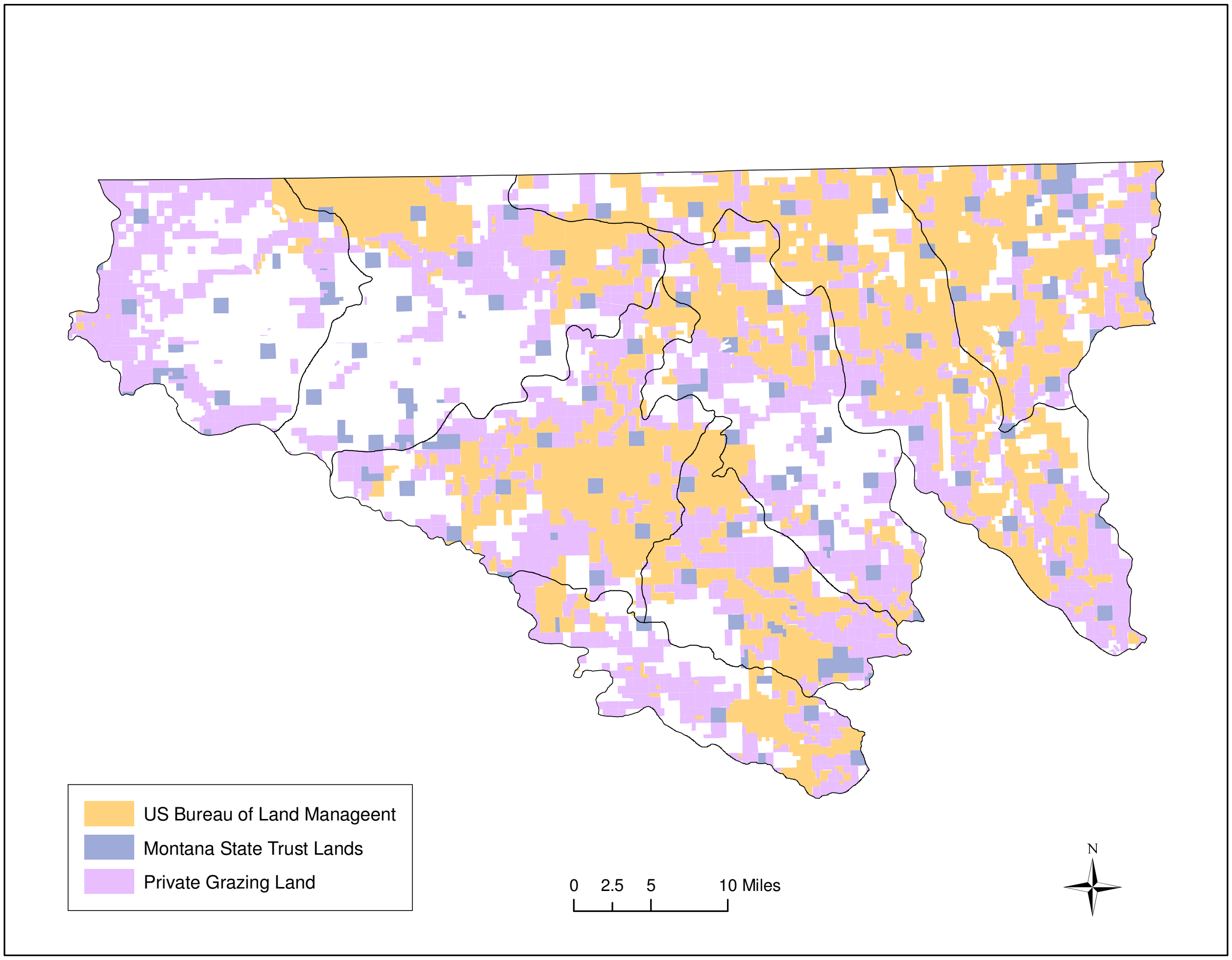


Figure 9. Public and private grazing lands

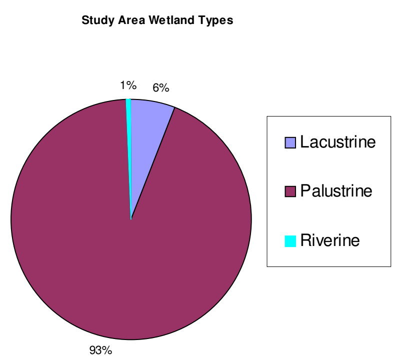


Figure 10. Wetland types across watershed

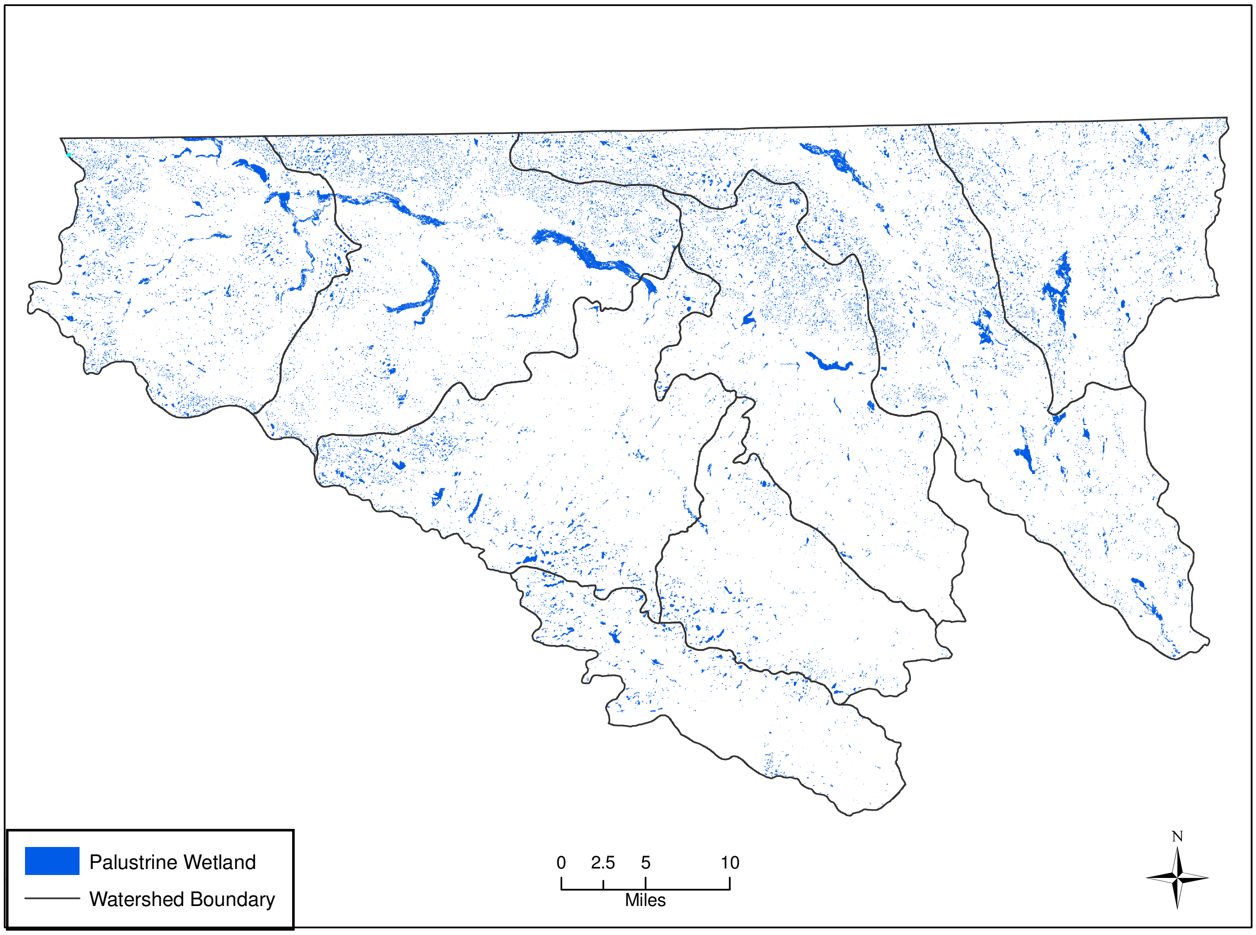


Figure 11. Palustrine wetlands in study area

Table 5. Hydrologically modified wetlands across study area and in 5th code HUCS

	Altered Palustrine	Altered Lacustrine	Unaltered Palustrine	Unaltered Lacustrine
	Acres	Acres	Acres	Acres
Whole Area	3919.73	1526.21	45986.88	1785.4
BlackCoulee	401.03	36.99	1425.08	0.0
Buckley	207.44	108.74	10874.62	0.0
EastFork	560.32	454.13	5080.57	1141.93
Muray	167.6	61.59	7975.74	172.16
Sneider	556.17	0.52	4285.31	82.76
Stinky	645.98	72.14	1613.74	0.0
Whitewater	758.02	126.16	9952.8	23.59
WoodyIsland	660.15	665.94	4742.05	364.96
	Altered Palustrine	Altered Lacustrine	Unaltered Palustrine	Unaltered Lacustrine
	%	%	%	%
Whole Area	7.9	46.1	92.1	53.9
BlackCoulee	22.0	100.0	78.0	0.0
Buckley	1.9	100.0	98.1	0.0
EastFork	9.9	28.5	90.1	71.5
Muray	2.1	26.3	97.9	73.7
Sneider	11.5	0.6	88.5	99.4
Stinky	28.6	100.0	71.4	0.0
Whitewater	7.1	84.2	92.9	15.8
WoodyIsland	12.2	64.6	87.8	35.4

Excavation, Ditching and Draining of Potholes

Across the watershed, only 1.5% of the Palustrine wetland acreage has been excavated, drained or ditched based on NWI mapping. Black Coulee (3.4%) and East Fork Whitewater Creek (3%) watersheds have the highest percentage of Palustrine wetlands mapped as excavated, drained or ditched. However, even this amount of alteration is notably smaller within the context of the greater Prairie Pothole Region, where many watersheds have lost most of their wetlands. The lowest percentages of excavation and draining are found in Buckley Creek and Murray Coulee watersheds (both less than 1%).

There is no baseline (i.e. pre-alteration) data on vegetation types or hydroperiods, so it is difficult to assess the broader impact of alteration, especially in the case of excavation. Certainly excavation has increased the number of permanent ponds, and probably provides more habitat for those waterfowl and wading birds that need standing water during nesting and rearing periods. On the other hand, excavation may have caused a decrease in surface area of individual potholes, favoring depth over area, and thus may have led to a loss of overall standing water acreage. Figures 12 and 13 are representative of excavated potholes. It appears that a smaller portion of excavated potholes has been ditched to drain water into other potholes or into excavated pits, perhaps as part of preparing sites for tillage, haying, or row cropping (Figure 14).

Figure 12. Excavated Pothole

Figure 13. Moat excavation

Figure 14. Ditch draining water from pothole into excavated pit

Impoundment of Potholes

Slightly over 6% of Palustrine wetlands in the area are impounded, with the highest percentages found in the Stinky Creek (27%) and Black Coulee (16.5%) watersheds, and the lowest percentages occurring in Murray Coulee (1.6%) and Buckley Creek (3.5%). Although some of these impoundments may occur in actual prairie potholes, it is more common for impoundments to have been built in intermittent or ephemeral drainages. Given the hydrology of potholes, and the infrequency of defined surface drainage channels, it is unlikely that many of them have been subject to such modifications. However, small drainages are sometimes rerouted by a combination of impoundment and ditching to channel water into existing potholes for stock watering. More specific evaluation of the degree of change that has occurred in the study area is impossible without baseline data.

Agricultural Runoff and Sedimentation

In the more agricultural portions of the study area, potholes and other Palustrine wetlands are often found in the midst of croplands. While these wetlands appear to be islands of natural habitat in the midst of a human-altered matrix, they are, of course, influenced by the surrounding land uses, receiving inputs of sediment, nutrients, and agricultural chemicals. As low points on the landscape, with minimal or no flow-through hydrology, these isolated wetlands can be severely impacted. Even areas that have been fallowed to rest the land or to meet Conservation Reserve Program guidelines are still sources of sedimentation from wind and water erosion, and wetland function can be seriously compromised when sediments build up in, and ultimately fill, the shallow depressions (Gleason and Euliss 1998).

The distribution, abundance, and reproductive success of ducks in the Prairie Pothole Region is influenced by a suite of environmental conditions, but agriculture and water level fluctuations are the dominant factors (Batt et al. 1989). The impacts of agriculture can be direct, as is the case with drainage, tillage, and conversion of grassland to cropland, or indirect, such as off-site erosion, fire control, road-building, and other land disturbances. Together, these cumulative effects can have long-lasting and severe consequences for waterfowl (Swanson and Duebbert 1989).

Invertebrates are a fundamental base of pothole food chains, exercising bottom-up controls on productivity and nutrient cycling. Like waterfowl, species and communities can be directly affected by agricultural chemicals (Grue et al. 1989), and by elevated sediments, nutrient enrichment, water-level fluctuations, and changes in surrounding ecological communities that often accompany agriculture (Euliss et al. 1999).

From GIS analysis of the National Land Cover Database, it appears that approximately 35% of the watershed is in agricultural use (hay, small grain, row crops, or fallow). Twenty-seven percent of the land within 100 meters of lentic wetlands and 9% of the land surrounding perennial and intermittent streams is in such use. This is a significant amount of agricultural use, especially given the high percentage of land identified as “Fallow,” i.e. plowed but not planted: 19% overall, 14% within the lentic wetland buffer, and 10% within the stream corridor buffer. With no vegetation to control wind or water erosion, fallow lands can have especially detrimental sedimentation impacts on wetland and riverine habitats.

Road Encroachment

Neither unimproved roads nor paved and gravel roads are in high number within the study area, and roads shown on local and BLM maps are often no more than a faint two-track through the prairie. However, roads do sometimes encroach on wetlands, particularly potholes, which are dry enough in summer months not to present a hazard to vehicles. Roads occasionally run through potholes (Figure 15), compacting or obliterating vegetation, creating surface runoff channels, compacting the soil, and offering bare soil for exotic species colonization. Such roads tend to be associated with gas developments or grazing, and are especially frequent in and around stockwatering areas.

Figure 15. Road encroachment in pothole

Natural Gas Development

Natural gas extraction is concentrated in the eastern portion of the watershed, particularly in and around the Whitewater Creek drainage. Impacts on wetlands have been and will continue to be both direct and indirect. In some instances, underground pipelines have been run directly through potholes, directly affecting hydrology, soil, and vegetation. Indirect effects, which cannot be quantitatively assessed without baseline data, come from road development and well site construction and operation. These effects are likely to include soil compaction, topsoil disturbance and loss, native vegetation removal, exotic species introductions, wind and water erosion across bare soils, and sedimentation. Wetland-dependant wildlife may suffer from direct habitat loss if and when development occurs within wetlands, or by displacement caused by construction, road traffic, or drilling (TRC Mariah Associates, Inc. 2000; USDI BLM et al. 2003).

Broad-Scale Assessment Indices

As part of the Whitewater Watershed report (Crowe and Kudray 2003), the Montana Natural Heritage Program developed a method for broad-scale assessment of wetlands based on a procedure originally developed by the Northeast Region of the U.S. Fish and Wildlife National Wetland Inventory Program (Tiner et al. 2000). For this project, we have refined the method to provide a better baseline for assessment, and to more accurately evaluate the stressors found in western watersheds.

We broke the assessment procedures into three parts. The first part uses a Composite Natural Diversity Index, based on underlying soil, elevation, and wetland mapping, to capture the extent and variation of natural conditions within the overall study area and the individual watersheds. The second part uses four sub-indices of habitat extent and three sub-indices of disturbance to produce the overall Composite Wetland Condition Index (CWCI). This index gives a sense of how much pre-settlement habitat remains in the study area and watersheds, emphasizing wetland and riparian systems and adjacent upland habitat, i.e. buffers. The third part is a Composite Wetland Threat Index. Because both grazing and non-grazing agriculture have the potential to degrade wetlands over time, we have included them both as current disturbances and future threats. We have also added sub-indices for agricultural conversion and drought.

One criticism of indices of biological integrity is that individual characteristics of the system being assessed are blurred by the act of collapsing multiple metrics into a single number (Moyle et al. 1999). To offset this danger, we have chosen to keep the three overall indices distinct from one another. This way, characteristics of each watershed can be compared without significantly diminishing the magnitude of specific disturbances or threats.

Effective buffer widths vary with respect to particular ecological functions (Castelle et al. 1994). Specific effective widths are not known for every function in the prairie pothole landscape, so we used three conservative widths for this assessment. The two disturbance indices determine how much wetland area has been altered since presettlement times. Each index ranges from 0.0 to 1.0. For the habitat indices, values closer to 1.0 indicate greater extent of intact habitat within the watershed. For the disturbance indices, values closer to 1.0 indicate greater disturbance of wetlands. The habitat indices are added together and the disturbance indices are subtracted from this sum to create the CWCI for the watershed.

Natural Diversity Indices

Diversity indices are mathematical measurements of community composition. Typically, they are used to assess species diversity, but they can also be used at the landscape level (Rosenzweig 1995). Instead of simple measures of richness, i.e. number of different ecosites, elevation bands, and wetland types, they provide a measure of relative abundance, or distribution of sites, bands, or types across the whole area. We used two common pairs of diversity measures as the starting point for these calculations. The first pair is Shannon's Diversity Index and Equitability Index (E).

In the Shannon Index (Shannon 1948), diversity (H) is calculated as:

$$H= -\Sigma(\boldsymbol{p_i}*\mathbf{ln}\boldsymbol{p_i}),$$

where $\boldsymbol{p_i}$ is the proportion of acres of site, band or type relative to the total number of acres in the area of interest, and $\mathbf{ln}\boldsymbol{p_i}$ is the natural logarithm of this proportion.

Equitability (E) is a value between 0 and 1, and measures the evenness of distribution across an area of interest. It is calculated as:

$$E= H/\mathbf{lnS},$$

where **lnS** is the natural log of the total number of sites, bands, or types present.

One shortcoming of the Shannon Diversity Index is that it sometimes over represents rare types, which was not a concern for topography, but did come up when assessing the diversity of ecosites and wetlands. To offset this, we also calculated Simpson's Diversity Index, which is less sensitive to rare types.

In the Simpson Index (Simpson 1949) diversity (D) is calculated as:

$$D= 1/ (\Sigma\boldsymbol{p_i})^2$$

Although equitability is expressed as a number between 0 and 1, calculated numbers for the diversity indices have no such limits. To facilitate comparison, we converted the absolute scores to relative scores by setting the highest diversity and equitability score on a given metric at 1, and taking all others as proportions. For the Ecosite Diversity Index and the Wetland Diversity Index, where we used both Shannon's and Simpson's Diversity Index, we combined and averaged the two relative scores. Since there were no rare types in the Topographic Diversity Index calculation, we used only the relative Shannon's Index. We found that Shannon's Equitability represented evenness of types across the study area well, and so we used it as the single measure of evenness.

Ecosite Diversity Index (I_{ED})

The ecosite diversity index characterizes the relative abundance of different ecosite types in individual watersheds relative to the total land area in that watershed. Ecosites reflect the underlying geology, soils, precipitation regime, and landforms, and therefore influence natural community composition, habitat availability, and agricultural potential (USDA NRCS 2003). There are 28 different ecosites in the study area as a whole (Table 1), ranging from clay pan to wet meadow.

Table 6. Ecosite Diversity scores

	Composite Relative Diversity	Relative Shannon Equitability
Whole	0.66	0.75
BlackCoulee	0.66	0.94
Buckley	0.57	0.69
East Fork	0.41	0.53
Murray	0.47	0.58
Sneider	0.58	0.74
Stinky	0.54	0.72
Whitewater	0.55	0.7
Woody	1	1

Based on ecosite types, Woody Island Coulee is the most diverse of the 5th code watersheds, and has the most equitable distribution of types. East Fork Whitewater is the least diverse, and the types represented there are not especially well-distributed.

Topographic Diversity Index (I_{TD})

Like ecosites, topography influences plant community composition and habitat availability for animal populations. The more topographic diversity within a watershed, the more niche habitat and microhabitat available, and the higher the chance of finding rare types while ensuring broad representation of species found across the watershed as a whole. Elevations in the study area range from 660 to 1080 meters (2200 to 3600 feet) above sea level (Table 7).

Table 7. Topographic Diversity Scores

	Relative Shannon Diversity	Relative Shannon Equitability
Whole	1	0.95
Black Coulee	0.8	0.89
Buckley	0.71	0.91
East Fork	0.84	0.96
Murray	0.78	0.93
Sneider	0.74	0.81
Stinky	0.78	0.86
Whitewater	0.93	1
Woody	0.82	0.96

The study area as a whole has the greatest diversity, although it is not the most even; here, the large size ensures the best representation but diminishes the equitability of distribution. Of the 5th code watersheds, Whitewater Creek is the most topographically diverse, with the most equitable distribution of elevation bands, while Sneider Coulee is both the least diverse and the least even.

Wetland Diversity Index (I_{WD})

In the NWI system, wetland types reflect differences in landform, water source, hydroperiod, and plant communities. As such, they also represent diverse habitats. The more wetland types in a watershed, and the better their distribution, the more habitat is spatially and temporally available, and the more likely it is that plants and animals can survive the loss or disturbance of individual wetlands or wetland complexes. There are 14 different wetland types represented in the study area as a whole, if altered wetlands are not counted. Although we recognized that some hydologically altered wetlands may provide specific types of habitat (e.g. certain excavated wetlands, as discussed above), we were more concerned with gauging the extent of diversity in the absence of human use, and so we excluded altered wetlands from the calculation (Table 8).

Table 8. Wetland Diversity Scores

	Composite Relative Diversity	Relative Shannon Equitability
Whole	0.73	0.62
Black Coulee	0.72	0.72
Buckley	0.53	0.74
East Fork	1	1
Murray	0.64	0.77
Sneider	0.74	0.85
Stinky	0.58	0.83
Whitewater	0.67	0.66
Woody	0.33	0.85

The East Fork Whitewater watershed has the highest relative diversity, and the highest equitability score. Woody Island Coulee has the lowest diversity score, although it ranks high on evenness.

Because of its large size, the study area as a whole has the lowest equitability score.

Composite Natural Diversity Index (CNDI)

We combined the three diversity indices and equitability index composite measures of overall diversity and overall equitability. Then we combined and averaged the diversity and equitability scores to obtain a single score for Overall Natural Diversity.

These scores are shown below. The study area as a whole is presented first; the 5th code HUCs are ranked in order according to the highest score (Table 9).

Table 9. Composite Natural Diversity Index

	Composite Diversity Index	Composite Equitability Index	Overall Diversity Score
Whole	2.39	2.31	2.35
Woody	2.15	2.81	2.48
East Fork	2.25	2.48	2.37
BlackCoulee	2.17	2.55	2.36
Whitewater	2.15	2.36	2.26
Sneider	2.06	2.4	2.23
Stinky	1.91	2.42	2.16
Murray	1.89	2.28	2.09
Buckley	1.8	2.34	2.07

Based on diversity alone, East Fork Whitewater would have the highest ranking, but the relative equitability of distribution across the three metrics pushed Woody Island Coulee to the top. Buckley Creek has the lowest diversity and lowest overall diversity score. It is interesting to note that the study area as a whole would rank fourth in overall diversity. This is primarily because of the large area across which the various sites, bands and types are spread, resulting in inequitable distributions.

Composite Wetland Condition Index

The Composite Wetland Condition Index is made up of seven sub-indices. Four habitat extent indices measure the degree to which the watersheds in the study area retain the natural conditions that are believed to have existed prior to Euro-American settlement: the Natural Cover Index, the Natural Communities Index, the Stream Corridor Integrity Index, and the Lentic Wetland Buffer Index. Each of these indices has a score between 0 and 1, with 0 representing the greatest departure from natural conditions, and 1 representing the least departure. These four indices are complemented by three disturbance indices that assess the extent of alterations and other disturbances affecting wetlands: the Wetland Direct Disturbance Index, the Diverted Stream Flowage Index, and the Road Disturbance Index. Each of these indices also has a score between 0 and 1, with 0 representing the lowest level of disturbance and 1 the highest. To arrive at an overall determination of wetland condition, we summed the four condition sub-indices and then subtracted the summed disturbance sub-indices.

Habitat Extent Indices

Natural Cover Index (I_{NC})

The natural cover index measures the ratio of grassland, forest, shrubland, and wetlands to the total land area in the watershed. Because human activities in watersheds can have far-reaching effects on wetland hydrology, water quality, vegetation, soil development, and nutrient cycling at both the site and watershed scale, more land in natural cover within a watershed can be taken as a positive indicator of overall condition. Inversely, a low score can be interpreted as an indication of the amount of area in a given watershed that is contributing to negative changes in wetland function.

The Natural Cover Index was initially developed for use in the Northeast, where livestock grazing is not as widespread, and consequently it does not account for the impacts of grazing on natural cover. Although grasslands in the western U.S. evolved under grazing regimes, the brief, intense grazing patterns characteristic of bison and elk are not reproduced by cattle, and plant community composition can shift radically under continued, season-long grazing, especially if cattle are stocked heavily. Therefore, we added a second calculation to the Natural Cover Index initially developed by Tiner (2000).

Table 10. Natural and human land cover and uses

Natural land cover	All	Black Coulee	Buckley	East Fork	Sneider	Murray	Stinky	Whitewater	Woody
	acres	acres	acres	acres	acres	acres	acres	acres	acres
Open Water	3809	374	133	228	410	81	576	557	1451
Bare Rock Sand or Clay	2855	766	2	1	424	2	118	18	1525
Deciduous Forest	1045	155	48	248	197	15	48	204	129
Evergreen Forest	3169	601	115	178	356	58	99	865	896
Shrubland	27301	3769	3578	1926	3521	1712	1166	3724	7920
Grassland or Herbaceous	693758	63809	79341	84958	83445	66919	49177	161280	104669
Woody Wetlands	1887	29	58	538	257	423	98	330	155
Herbaceous Wetlands	6940	45	2460	868	147	1051	39	1304	1034
Total	740763	69547	85736	88944	88757	70261	51321	168282	117779

Human Land cover and use	All	Black Coulee	Buckley	East Fork	Sneider	Murray	Stinky	Whitewater	Woody
	acres	acres	acres	acres	acres	acres	acres	acres	acres
Low Intensity Residential	108	0	73	0	0	0	0	35	0
Commercial, Industrial, Transportation	282	16	11	0	101	0	13	141	0
Quarries, Mines or Gravel Pits	149	0	0	0	0	0	0	0	0
Pasture or Hay	8383	13	4454	589	1339	9	3	1706	278
Row Crops	1637	10	1347	93	34	87	31	25	15
Small Grains	175172	8230	43538	12830	25667	29680	14947	20099	20354
Fallow	212523	12434	47988	19256	28031	43006	14573	27135	20198
Urban or Recreational Grass	3	0	3	0	0	0	0	0	0
Total	398258	20703	97414	32768	55173	72782	29567	49142	40845

The original index is calculated as:

$I_{NC} = A_{NV}/A_W$,

where A_{NV} = area in natural vegetation in acres, and A_W = total area in watershed in acres minus the area occupied by open water.

For the study area as a whole and the eight subwatersheds, this calculation would yield the following results (Table 11):

Table 11. Natural Cover Index scores, ranked

Whole	0.65
Whitewater	0.77
BlackCoulee	0.76
EastFork	0.73
Woody	0.73
Stinky	0.63
Sneider	0.62
Murray	0.49
Buckley	0.47

From this metric, the watershed most closely approximating a natural land cover state is the Whitewater watershed, with a score of 0.77, followed by Black Coulee watershed, with a score of 0.76. Both score higher in natural cover than the watershed as a whole. Buckley Creek has a score of 0.47, indicating that slightly more than half its land cover has been altered by human uses (Table 10).

We added a second calculation,

NC_{ng}/TNC,

where NC_n = the area of natural cover from the National Land Cover Database that is not within BLM allotments or State Trust Lands, and is not private land with grazing indicated as its primary use in cadastral records, and TNC = the total natural vegetation cover in the watershed.

To arrive at a modified Natural Cover index that reflects western land use, we combined the two calculations so that:

$I_{NC} = [(A_{NV}/A_{W)} + (NC_{ng}/TNC)] / 2$

With this modified Natural Cover Index, we arrived at the following (Table 12):

Table 12. Modified Natural Cover Index Scores, ranked

Whole	0.38
Whitewater	0.42
BlackCoulee	0.39
East Fork	0.38
Sneider	0.35
Stinky	0.35
Murray	0.34
Woody	0.29
Buckley	0.27

With grazing accounted for, the Natural Cover Index scores are much lower, and suggest that the acreage of undisturbed natural cover throughout the study area is actually quite low with the highest values in the Whitewater 5th code watershed just a bit above the average of 0.38. Buckley Creek, which scored low on the initial natural cover index, is even lower here, reflecting the additional impacts of grazing. Woody Island Coulee watershed dropped from 4th rank to 7th with grazing factored in, because only 5,443 of its 117,779 acres in natural land cover are not in public or private grazing lands.

Natural Communities Index (I_{NCom})

This index calculates the degree to which existing natural land cover classes correspond to the natural communities that would have existed prior to Euro-American settlement, based on soil and site data. Grassland, shrub, and riparian/wetland communities provide distinct and critical habitats, so we wanted to determine if there had been any broad changes in the amount of acreage available. While this calculation does not address such issues as patch size, connectivity, or habitat quality, it gives us a general benchmark to gauge habitat loss. To calculate it, we created three corresponding classes for the Natural Communities Map and the National Land Cover Database Map: a shrub/evergreen class, a grassland class, and a wetland/riparian class. We then divided the acreage in each NLCD group by the corresponding acreage from the Natural Communities Map and averaged the three scores into a composite index:

$I_{NCom} = \Sigma[(NLCD_{SE}/NatCom_{SE})+(NLCD_{G}/NatCom_{G}) +(NLCD_{WR}/NatCom_{WR})]/3,$

where $_{SE}$ =Shrub/Evergreen, $_{G}$ = Grassland/Herbaceous, $_{WR}$ =Wetland/Riparian, and NLCD and NatCom=National Land Cover Database and Natural Communities Map, respectively.

The scores are shown in Table 13. In general, they suggest relatively little loss of Wetland/Riparian acreage, and relatively high loss of Shrub/Evergreen acreage, with grasslands somewhere in between. There is also considerable variation among watersheds. For example, Murray Coulee scores extremely low on the Wetland/Riparian component, indicating a high rate of habitat loss, which Buckley Creek appears to have gained significant amounts of habitat. There are two possible explanations for the apparently high rate of wetland retention. One is a simple fact of the databases involved: since the Natural Communities data is based on 1:24,000 soil and ecosite data, the small wetlands that can be detected by aerial photography (i.e. NLCD methods) may fail to appear on lower-resolution maps of hydric and non-hydric soils. A second possibility is that there has actually been a net gain of wetlands in some

Table 13. Natural Communities Index, ranked

	Shrub/ Evergreen	Grassland	Wetland/ Riparian	Composite Index
Whole	0.41	0.7	1.09	0.74
Black Coulee	0.69	0.98	1.35	1
Buckley	0.26	0.47	2.21	0.98
East Fork	0.49	0.75	1.71	0.98
Murray	1.07	0.62	0.23	0.64
Sneider	0.24	0.53	1.02	0.6
Stinky	0.36	0.71	0.61	0.56
Whitewater	0.25	0.83	1.29	0.79
Woody	0.54	0.87	1.53	0.98

watersheds, possibly due to excavation and impoundment. However, this would not explain the high score for Buckley Creek watershed, where relatively little excavation has occurred.

Stream Corridor Integrity Index (I_{SCCI})

The stream corridor integrity index measures the amount of natural land cover within a set buffer on either side of all perennial and intermittent streams that is occupied by natural open land. It was calculated by creating a 100-meter buffer on each side of the stream segments in the National Hydrography Dataset. (Although this dataset is based on 1:24,000 USGS topographic maps, it has a usable scale of only 1:100,000, and so does not fully represent ephemeral drainage. This index offers a way to determine whether areas adjacent to streams are contributing more than natural amounts of sediment, runoff and pollution. Croplands and fallow fields will produce higher sedimentation rates than naturally vegetated areas (Wilkin and Hebel 1982), and activities that create impermeable cover (particularly roads and commercial, industrial or residential development) will lead to elevated runoff levels, as well as overland transport of chemical pollutants.

We calculated this index as:

$I_{SCI} = A_{VC}/A_{TC}$,

where A_{VC} = naturally vegetated stream corridor area, in acres, and A_{TC} = total stream corridor area, in acres (minus area occupied by open water bodies) (Table 14).

Table 14. Stream Corridor Integrity Index, ranked by subwatershed

Whole	0.8
Black Coulee	0.9
Whitewater	0.87
Woody	0.87
Buckley	0.83
East Fork	0.8
Stinky	0.79
Sneider	0.74
Murray	0.56

We chose 100 meters as the buffer width on each side (200 meters total), but we found little difference between scores calculated with 50, 10, and 150 meter buffers. For the most part, these scores are high, indicating that there is fairly limited agricultural and commercial or residential development around perennial and intermittent streams, except in Murray Coulee. Murray Coulee, it should be noted, has one of the highest numbers of acres of cropland and fallow land, and the lowest level of public land ownership of all the 5th code HUCs. Much of it lies atop the Big Flat area underlain by Flaxville Gravels, and the relative homogeneity of the topography, as well as the productive aquifer on Big Flat, makes it ideally suited for agriculture.

As noted earlier, the simple fact of natural land cover does not in itself guarantee that streams are not impacted by human activities, especially since the great majority of natural land cover in the study area is subject to grazing. We did not try to capture the impact of grazing here, because it has already been incorporated into the modified Natural Cover Index. However, grazing impacts on stream corridors can be especially severe, and the high scores on the Stream Corridor Integrity Index should be taken in context, especially in watersheds like Woody Island Coulee, where grazing acreage is high.

Lentic Wetland Buffer Index (I_{LWB})

Like the Stream Corridor Integrity Index, the wetland buffer index is a measure of the extent of natural land cover within a given buffer around all lentic wetlands. To assess this, we buffered all NWI lentic wetland polygons by 100 meters, then dissolved the buffers so that acreage would not be double- or triple-counted when buffers overlapped, as they often did in basins where potholes are numerous. We chose 100 meters rather than 50 or 150 simply because it was a midpoint, and the differences between scores derived at each width were minimal.

This Lentic Wetland Buffer Index is again premised on observations that croplands, roads, and commercial or residential developments are more likely to be sources of sediment, pollutants, and runoff for lentic wetlands than are natural land covers (Wilkin and Hebel 1982).

We calculated the index as follows:

$\mathbf{I_{LWB}} = A_{VB}/A_{TC}$,

where A_{VB} = naturally vegetated wetland buffer area, in acres, and A_{VB} = total wetland buffer area (minus area occupied by open water bodies), in acres.

Table 15 shows the score for the whole study area, and for the 5th code HUCs in ranked order. Three of the watersheds, Whitewater Creek, East Fork Whitewater, and Sneider Creek have higher scores than the study area as a whole, while the rest are below that score (0.73). Black Coulee, Murray Coulee and Stinky Creek have the lowest score, all at 0.63. Black Coulee watershed ranked relatively high on the unmodified Natural Cover Index, so it is somewhat surprising to see a low rank on this metric. However, we also noted earlier that Black Coulee and Stinky Creek watersheds have the highest level of hydrological modification of wetlands, so it may be that the distribution of wetlands is simply disproportionately concentrated in areas most desirable for agriculture.

Table 15. Lentic Wetland Buffer Index, ranked

Whole	0.73
Whitewater	0.83
East Fork	0.82
Sneider	0.77
Buckley Creek	0.68
Woody	0.66
Black Coulee	0.63
Murray	0.63
Stinky	0.63

Wetland Disturbance Indices

Wetland Direct Disturbance Index ($\mathbf{I_{WDD}}$)

Surrounding land use can affect large areas of wetlands, especially when a landscape has the kind of concentration of wetland sites that is characteristic of the Prairie Pothole Region, and so overall wetland condition indices, like the one above, can give us useful insights into broad trends. Another approach is to look at the number of mapped disturbances directly affecting wetlands. To derive this index, we looked at two kinds of direct disturbance: hydrological alteration and stockwatering. It is not uncommon within the study area to see salt and supplement barrels in or immediately adjacent to potholes, and potholes with standing water are favorite haunts of cattle, both for drinking and loafing. To calculate this index, we grouped NWI polygons with hydrological modification (diked, impounded, partially drained/ ditched or excavated), summed the acres in that class, and created a layer of otherwise unaltered wetlands with stockwatering points in the wetland or within a 10 meters buffer. We chose the 10 meter buffer to allow for a degree of imprecision in both the mapping of stockwater rights and the behavior of cattle, assuming that wetlands within 10 meters of a stockwatering point would be more likely to be trampled by cattle or receive nutrient inputs from manure deposits. This index was calculated as:

$\mathbf{I_{WDD}} = (A_{HM}+A_{SW})/A_{TW}$,

where A_{HM} is the area of hydrologically modified wetlands, in acres, A_{SW} is the area of wetlands within 10 meters of a stockwatering point, in acres, and A_{TW} = the total area of wetlands in the area of interest, in acres.

The results of this calculation (Table 16) indicate that more than a third of the wetlands across the

Table 16. Wetland Direct Disturbance Index, ranked

Whole	0.35
Stinky	0.48
EastFork	0.42
BlackCoulee	0.39
Sneider	0.36
Woody	0.35
Buckley	0.35
Whitewater	0.34
Murray	0.25

study area have some direct disturbance, whether as a result of hydrological alteration or stockwatering activities. Stinky Creek watershed has the highest level of disturbance, while Murray Coulee has the lowest. As we noted earlier, Murray Coulee has the lowest percentage of excavated and drained wetland acreage, which explains this score.

Diverted Stream Flowage Index (I_{DSF})

Both dams and surface water diversions change the hydroperiodic flows in a watershed, and deprive riparian communities of the water needed for proper ecological functioning. Dams also trap fine sediments, disrupting normal geomorphological change downstream, and alter the substrate behind them, affecting macroinvertebrate colonization and food chain dynamics. The diverted stream flowage index is a ratio of the number of dams and surface water diversions to miles of stream. Because many of the water rights records are not accurately georeferenced, but only keyed to Township and Range, we could not produce an accurate layer of free-flowing stream segments versus dammed stream segments. This method, while not completely capturing the impact of diversions and withdrawals, at least gives a basis for comparing the degree of stream alteration between 5th code HUCs.

$I_{DSF} = 1 - (L_{TS}/ (N_D + N_{Div}))$,

where $L_{TS;}$= length of mapped perennial and intermittent streams in miles, N_D is the number of dams, and N_{Div} is the number of non-dam surface water diversions.

Scores vary widely between the 5th code HUCs (Table 17).

Table 17. Diverted Stream Flow Index, ranked

Whole	0.91
Whitewater	0.96
Buckley	0.96
East Fork	0.95
Sneider	0.91
Stinky	0.69
Woody	0.68
Black Coulee	0.6
Murray	0.46

The relatively low score for Murray Coulee watershed is again probably attributable to two factors: first, the large quantities of water underlying the Flaxville Gravels, since groundwater is likely to be a better source for agricultural use than surface water, and second, the prevalence of dryland farming as a land use in the watershed.

Conversely, the high scores for the Whitewater and the East Fork Whitewater watersheds may reflect the relatively paucity of ground water found in the Judith River formation, and the high demands put on water by human activities, including oil and gas development in the area.

Despite the range of scores, this index indicates that surface water is a highly manipulated resource throughout the study area, and that free-flowing channels are probably rare. In the Whitewater watershed, for example, there are 5,654 surface water dams and diversions, and only 208 miles of perennial and intermittent streams. Many of these dams and diversions probably occur in ephemeral drainages, which are not accounted for in the calculated index, but these dams are likely to be impounding or diverting water that would otherwise flow into the intermittent and perennial reaches.

Road Disturbance Index (I_{RD})

Both improved and unimproved roads compact or cover soil and vegetation, increasing surface runoff. Road rights of way are often fertile ground for exotic species to colonize, and unimproved roads contribute to wind and water-borne erosion and sedimentation. Streams and wetlands in close proximity to roads are more likely to be affected by roads than those at a greater distance. This index is a ratio of the acres of wetlands and miles of streams within 50 meters of either side of a road. We chose the 50 meter buffer instead of a larger and more conservative buffer only because roads in the area are lightly traveled, and many are simply two-tracks in the prairie. The Road Disturbance Index is calculated as:

$\mathbf{I}_{RD} = [(A_{WR}/A_W)+(L_{SR}/L_S)]/2$,

where A_{WR} =the area of wetlands within 50 meters of a road, in acres, A_W = the total area of wetlands, in acres, L_{SR} = the length of perennial and intermittent streams within 50 meters of a road, in miles, and L_S = the total length of perennial and intermittent streams.

For the study area and 5th code HUCs (Table 18).

Table 18. Road Disturbance Index, ranked

Whole	0.37
Woody	0.49
Buckley	0.45
Murray	0.43
Stinky	0.41
Whitewater	0.39
East Fork	0.29
Sneider	0.29
Black	0.16

In general, these numbers are low, indicating that roads are not a major source of disturbance in the study area. The highest scores, predictably, are in the watersheds with the greatest road density, and it might be just as effective to use road density itself as an index, rather than buffering and overlaying roads on streams and wetlands.

In the calculations, the road/stream relationship tended to be strong, with 50% or more of the streams in every watershed except Black Coulee being within 50 meters of a road. This probably reflects road-builders taking the path of least resistance through valleys and stream corridors, as well as early settlement patterns, which tended to be concentrated in valley bottoms. Wetlands, by contrast, are more evenly distributed across the landscape, and are more likely to escape the impacts of roads. It may be useful, in subsequent studies, to parse this index out in two separate sub-indices, especially if stream resources are the focus of concern.

Composite Wetland Condition Index (CWCI)

The Composite Wetland Condition Index is calculated by subtracting the combined disturbance indices from the combined habitat extent indices:

$\mathbf{CWCI = (I_{NC} + I_{Ncom} + I_{SCCI} + I_{LWB}) - (I_{WDD} + I_{DSF}} + I_{RD})$

The highest possible score would be 4.00, assuming scores of 1.00 (best) on each of the habitat extent indices and 0.00 (best) on each of the disturbance indices. Actual scores for the study area as a whole and the 5th code watersheds are much lower (Table 19).

Table 19. Composite Wetland Condition Index, ranked

Whole	1.02
Whitewater	1.58
Woody	1.5
Black	1.41
East Fork	1.32
Sneider	1.12
Buckley	1
Stinky	0.76
Murray	0.58

The Whitewater watershed ranks highest, with a score considerably above that of the study area as a whole, indicating that it is in better shape than some of its neighbors. Murray Coulee ranks much lower than the study area as a whole, and a full point lower than Whitewater. Overall Natural Diversity Index, but the scores on that index were not dramatically different from one another. Here, Murray Coulee's score is much lower than those of the other 5th code HUCs, , suggesting that human activities since Euro-American settlement have had serious impacts on watershed integrity. By contrast, the Whitewater watershed had an Overall Natural Diversity Index score in the middle range. The fact that its CWCI score is at the top of the list indicates that watershed integrity has stayed relatively high. By contrast, the Whitewater watershed had an Overall Natural Diversity Index score in the middle range. The fact that its CWCI

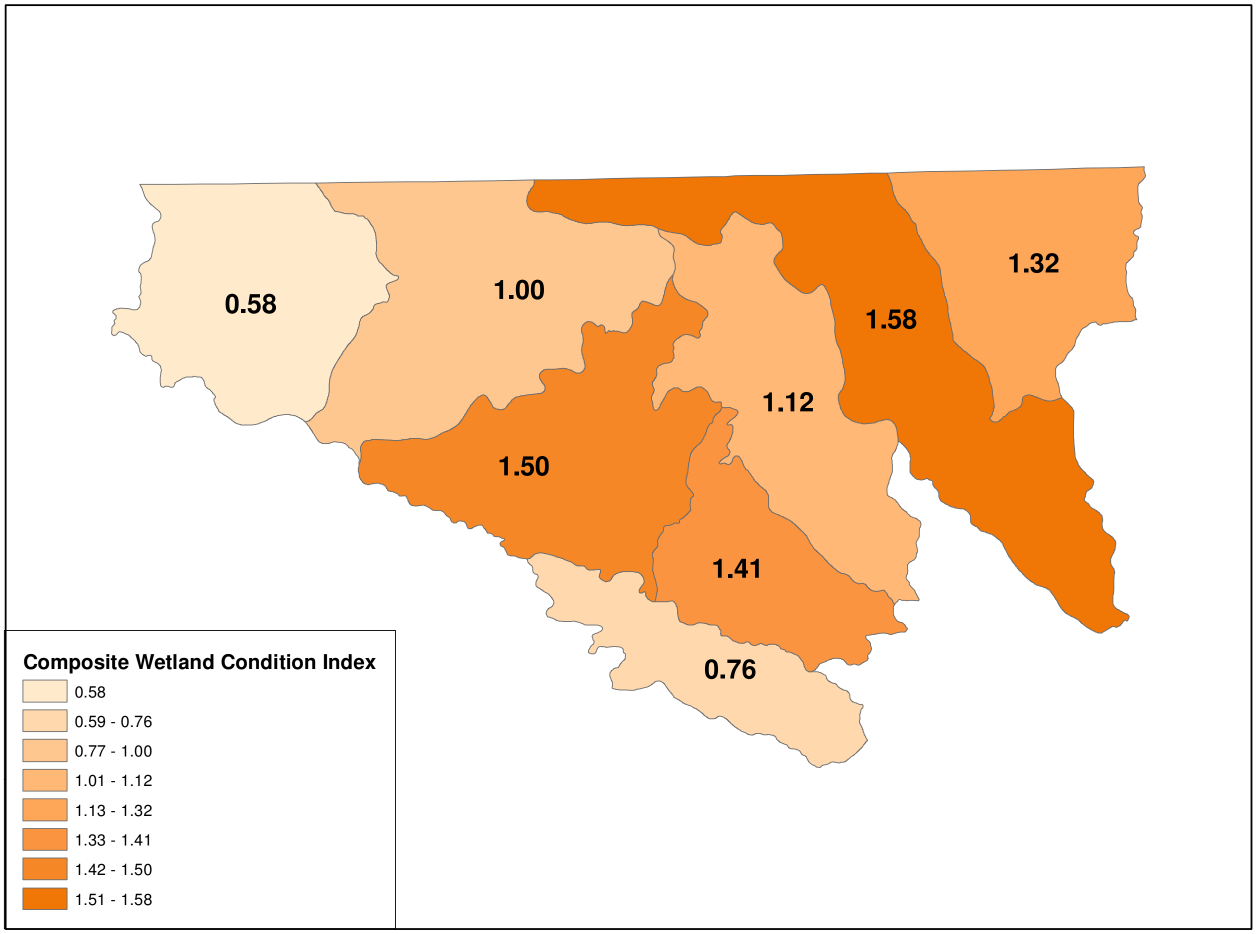


Figure 16. Composite Wetland Condition Index

score is at the top of the list indicates that watershed integrity has stayed relatively high.

Wetland Threat Indices

The Composite Wetland Condition Index is a measure of how much natural conditions have changed across the study area, and in individual watersheds, since Euro-American settlement. To a certain degree, the rate of change in the study area has probably slowed in the past few decades. Road- and dam-building, wetland excavation, homestead establishment and prairie-busting would have been most intense in the first few decades of settlement, and absent dramatic changes in demographics or agricultural production incentives, are unlikely to resume at the same level in the future. However, many of today's practices will have long-lasting and cumulative impacts on wetlands, and both natural and economic factors may affect watershed health in the future (Figure 16).

Some potential threats are real but unpredictable, and therefore beyond the scope of this analysis. For example, natural gas development, already underway in the Whitewater watershed, could become widespread if sufficient gas reserves were found, or if the continuing upward push on natural gas prices makes the development of marginal reserves an economically feasible proposition. Exotic species, largely absent from the watershed, could make rapid incursions if conditions were right, and if a source of seeds or plants made inroads into the area. Futuristic imaginings might anticipate a sudden population influx into, or exodus from, the area, depending on local economic conditions.

In this section, we examine four of the many possible threats. Two, grazing and agriculture, are in the category of cumulative impact threats, i.e. conditions that are ongoing and that tend to have worsening impacts over time. One, agricultural conversion, is more speculative, although the consolidation of farms and increasing fuel and equipment costs may make production increases more attractive. The fourth threat, drought, is already in play. While these threats are not exhaustive, they may provide some insight into the susceptibility of the individual watersheds to future change.

Wetland Grazing Threat Index (I_{GT})

Cattle grazing can cause soil compaction, nutrient enrichment, vegetation trampling and removal, habitat disturbance, and, depending on the season and intensity of use, reproductive failure for both plants and animals. In riparian areas, grazing can cause stream bank destabilization, loss of riparian shade, and increased sediment and nutrient loads (George et al. 2002). We noted earlier that much of the natural land cover in the study area is within private or public grazing areas. Here, we assessed the extent of wetlands (Lacustrine, Palustrine, and Riverine) in those natural vegetation areas that are threatened by ongoing grazing. The Wetland Grazing Threat Index is calculated as:

$\mathbf{I}_{GT} = AW_G/AW_T$,

where AW_G is the area of wetlands within natural cover classes on public or private grazing lands, and AW_T is the total area of wetlands in the study area or watershed of interest.

In all watersheds except Black Coulee, over 70% of the wetlands are subject to grazing; in the Whitewater watershed, that figure rises to 86% Table 20). This does not mean, of course, that all individual wetlands are grazed, or that grazing intensity is equally high among all of them. Cattle often bypass a pothole entirely on well-worn paths to water or supplements. However, in our fine-scale assessments, we noted some degree of cattle impact (manure, pugging, grazing) on most of the wetlands we sampled. A separate index, below, attempts to assess the direct impacts of ongoing drought on wetland health; here, we note that especially in drought years, pothole vegetation will retain palatability and vigor longer than surrounding upland grasses. Therefore, a great percentage of wetlands within the study area are threatened by ongoing grazing, and this threat will be magnified if current drought conditions persist.

Table 20. Wetland Grazing Threat Index, ranked

Whole	0.78
Whitewater	0.86
Sneider	0.84
Buckley	0.82
EastFork	0.77
Stinky	0.74
Muray	0.73
Woody	0.71
BlackCoulee	0.61

Wetland Agricultural Threats Index (I_{WAT})

As we mentioned earlier, wetlands in agricultural areas are influenced by tillage, fertilization, weed control, planting and harvesting, receiving inputs of sediment, nutrients, and agricultural chemicals. Prairie potholes are especially vulnerable, because few have flow-through hydrology to flush out these excess inputs. Consequently, ongoing agricultural activity, even at current rates, poses a threat to wetland health. The Wetland Agricultural Threat Index mirrors the Wetland Grazing Threat Index, by taking a ratio of all wetlands within agricultural land use areas (the categories Pasture/Hay, Fallow, Row Crops, and Small Grains in the NLCD) to all wetlands within the study area or individual watershed:

$\mathbf{I}_{WAT} = AW_{AG}/AW$,

where AW_{AG} is the acreage of wetlands contained by areas mapped as having agricultural land cover, and AW is the total acreage of wetlands.

These numbers are very low (Table 21), indicating that there are few extent wetlands within agricultural land use categories. In another context, this could be interpreted as an indication of the amount of wetland loss during agricultural conversion, since one might assume that the natural density of wetlands per acre would be more or less uniform across individual watersheds. However, for the purposes of assessing current and future threats, this index shows that there is only a small threat from non-grazing agriculture.

Table 21. Wetland Agricultural Threat Index

Whole	0.04
Black	0.04
Buckley	0.05
EastFork	0.02
Murray	0.07
Sneider	0.03
Stinky	0.04
Whitewater	0.02
Woody	0.03

Potential Agricultural Threat index (I_{PAT})

Many of the farmsteads in the study area have been abandoned or lost to consolidation. Labor is hard to find in the more remote parts of the watershed, and a combination of the lack of labor, the cost of machinery, and the expenses associated with operation may make future agricultural conversion unlikely. However, demand by emerging markets, or a sustained rise in prices could change that. The Potential Agricultural Threat Index examines the types of natural communities that have been converted to agricultural use, and then measures the area of wetlands (Lacustrine, Palustrine, and Riverine) in such natural communities not currently under agricultural land use, but privately owned and therefore available for conversion. Since many of the parcels fitting these conditions (privately owned, agricultural potential determined by natural community, contain wetlands) are too small to be considered for conversion, we took a subset of parcels 40 acres or larger, then measured the acreage of wetlands therein.

$\mathbf{I}_{PAT} = (ALW_{PAT}/ALW)$,

where ALW_{PAT} =the area of wetlands subject to potential agricultural threat, and ALW is the area of all wetlands in the study area or watershed.

It appears from this index that potential agricultural threats are not evenly distributed across the study area. Murray Coulee has a threat index score of 0.46 (Table 22), which is fairly high, while East Fork Whitewater has a low 0.16. Land ownership is undoubtedly a factor in the spread, because Murray Coulee has the highest percentage of privately owned land, and East Fork the highest percentage of publicly owned land. Nevertheless, all but two of the 5th code HUCs have 20% or more of their wetlands at risk in the event of agricultural conversion on private lands.

Table 22. Potential agricultural threat index, ranked

Whole	0.25
Murray	0.46
Sneider	0.32
Stinky	0.24
Woody	0.23
Buckley	0.22
Whitewater	0.22
Black Coulee	0.16
East Fork	0.13

Drought Threat Index (I_{DT})

Prolonged drought has adverse effects on wetlands, especially those that rely on precipitation and surface runoff for recharge. The study area is in one of the drier portions of the Prairie Pothole Region, and so we can assume that it is highly susceptible to sustained drought. There is a small amount of variation in normal precipitation in the study area as a whole, with portions of Murray Coulee receiving average annual rainfall of 15 inches per year, while most of the central and eastern part of the study area receives only 12 inches. To capture what we assume would be a greater impact from drought in areas that are already low in average precipitation, we assigned a drought factor to each average annual precipitation band. We summed the acres of wetland in each precipitation band in each 5th code HUC and in the study area as a whole, divided them by total wetland acres, and then multiplied the result by the drought factor. Areas receiving 12 inches of precipitation a year had a drought factor of 0.5, 13 inches a drought factor of 0.4, 14 inches a drought factor of 0.3, and 15 inches a drought factor of 0.2, so that:

$$I_{DT} = \Sigma(AW_{PB}/AW * DF_{1,2,3,4} \ldots),$$

where AW_{PB} is the area of wetlands in a particular precipitation band, AW is the total area of wetlands, and $DF_{1,2,3,4}$ refers to drought factors 1, 2, 3 etc as described above.

Since several of the watersheds are completely within the lowest 12 inches per year average annual precipitation band, they receive the maximum score (Table 23), indicating that they are at greatest risk from drought. Murray Coulee, with the most variation in rainfall, as well as the highest annual averages, has the lowest threat score. All scores reflect that drought poses an elevated and ongoing threat in the whole study area and each of the watersheds.

Table 23. Drought threat index, ranked

Whole	0.47
Black Coulee	0.5
Sneider	0.5
Stinky	0.5
Whitewater	0.5
East Fork	0.49
Woody	0.47
Buckley	0.44
Murray	0.39

Composite Threat Index (CTI)

The Composite Threat Index is a simple sum of the four sub-indices, with the maximum possible score being 3.5, indicating a high degree of threats:

$$CTI = I_{GT} + I_{WAT} + I_{PAT} + I_{DT}$$

Table 24 shows the results for the study area and the individual watersheds. Overall, these scores are not extremely high, but they do indicate that threats to watershed and wetland integrity exist and are ongoing. For most of the watersheds, grazing and drought were the major threat components, with agriculture and agricultural conversion posing smaller threats. However, for Murray Coulee and Sneider Coulee, the two watersheds with the highest threat scores, threats were fairly evenly distributed. Murray Coulee, as indicated earlier, had a lower score on agricultural threats, but we have postulated that this may be because few wetlands still exist within agricultural areas in the watershed. On the other hand, Murray Coulee had a high score for agricultural conversion threats, because so much of the land is in private ownership. It is worth noting, too, that Murray Coulee's score would be quite a bit higher if such a high percentage of its extant wetlands did not occur within a small geographic area receiving above-average rainfall.

Table 24. Composite Threat Index, ranked

Whole	1.54
Sneider	1.69
Murray	1.65
Whitewater	1.6
Buckley	1.53
Stinky	1.52
Woody	1.44
East Fork	1.41
Black Coulee	1.31

Interpreting the Broad-scale Assessment Composite Indices

Although it may be tempting to continue to reduce the composite assessment indices to a single number, we have chosen to keep them separate because we think that each represents a distinct and important piece of the watershed assessment. The Composite Natural Diversity Index provides a basis for assessing the raw material, i.e. the range of natural variability within the individual watersheds. It may not furnish a complete picture of the study area in presettlement times, because we do not really know what wetland types (and therefore wetland diversity) may have been lost to human activities, but it gives the best approximation we have of natural conditions. The Composite Wetland Condition Index provides an overview of the magnitude of change in natural conditions, allowing us to compare individual watersheds and tease out factors, like the percentage of public and private ownership, or the extent of crop agriculture, that exert significant influence on overall condition. The Threat Index is a measure of what can still be lost. This index should be interpreted on its own, or at most in relation to the Composite Wetland Condition Index. For example, the Whitewater watershed ranks high on Composite Wetland Condition Index, relative to the other watersheds, and also has a fairly high Composite Threat Index score. Examining the component parts of the CTI, one thing that emerges is the threat from grazing, which is higher in the Whitewater watershed than anywhere else. This can be construed as an early warning to land and resource managers that focused attention on grazing is merited in this watershed, or as an indication that current management objectives are being met. Only on-site examination can determine which is the better interpretation, but the Composite indices provide a starting point for this and other inquiries.

Fine-scale Assessment

PFC Assessment of Lentic Wetlands

Figure 17 shows the locations of the 161 potholes and wetlands surveyed and assessed across the watershed. PFC assessments were done at 97 sites (some sites had more than one pothole). Of the 97 sites surveyed, 30, or 31%, were considered to be functioning-at risk (Figure 18). We rated a site as functioning at risk if it was hydrologically modified, had a road or pipeline through it, was

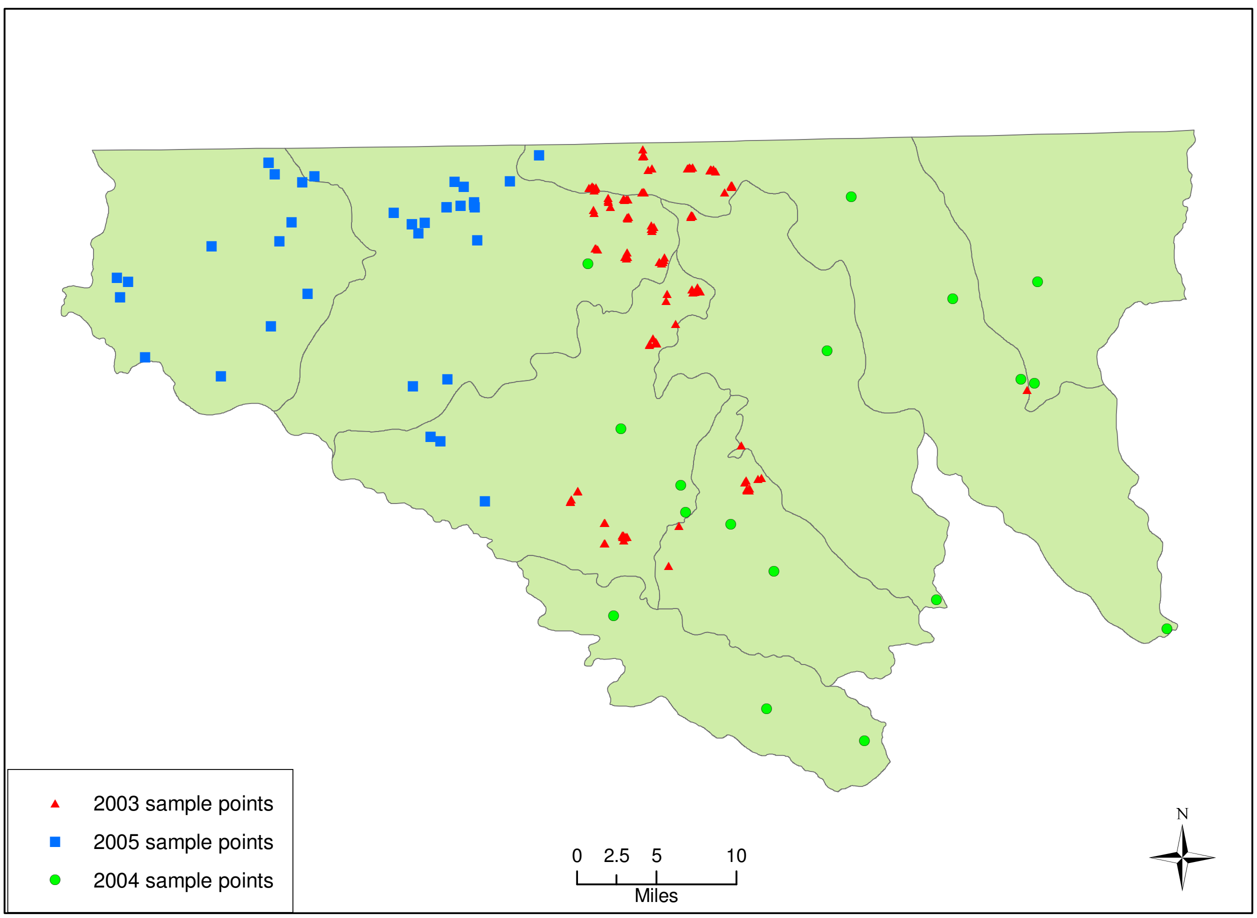


Figure 17. Location of field sampling sites

surrounded by uplands which were chisel plowed, or if grazing intensity was such that high levels of pugging or vegetation removal appeared to compromise wetland integrity. The most frequent modifications we encountered were dams and excavations for stock watering or waterfowl habitat improvement.

As was true in the earlier survey of the Whitewater watershed, there were some sites where it appeared that earlier modifications such as ditches and drains had been filled in, presumably as part of an effort to natural hydrologic function. This approach has been effective in restoring natural vegetation in other parts of the Prairie Pothole Region. In Iowa, natural vegetation recolonized sites where wetland hydrology had been restored (Seabloom and van der Walk (2003). However, it seems that the success of restoration efforts is largely dependent on flood regimes. In permanently flooded zones, vegetation is quickly restored, but recolonization takes longer in temporarily, seasonally and semipermanently flooded potholes (Galatowitsch 1993). The same author reported lower species richness and cover within the first few years following restoration, but surmised that most or all of the original flora would eventually return, assuming that exotic species did not invade during the recovery period. We saw very few exotic species in the study area as a whole, and discussions with county personnel indicated that weeds are not a substantial threat in the pothole area (Manoukian, 2005). Therefore, it is reasonable to conclude that restoration of hydrologic function has a good chance of successfully restoring natural vegetation communities, especially in the wetter potholes.

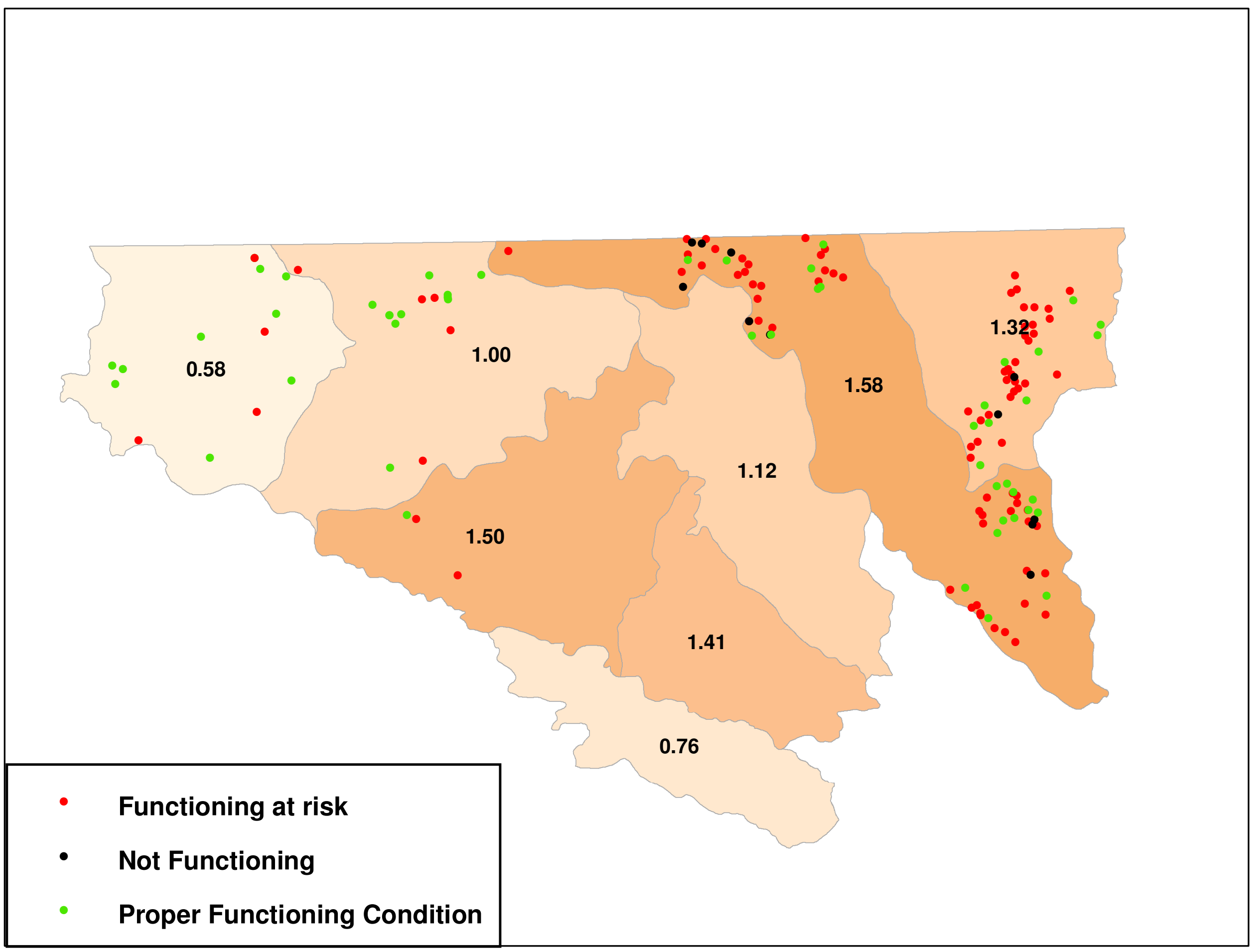


Figure 18. PFC score distribution

Vegetation Communities

Throughout the entire study area, pothole vegetation was strongly zoned, with the center of potholes having the most hydrophilic vegetation. Western wheatgrass-needleleaf sedge (Figure 19) was the most common and often the only community present at individual sites (see Table 25 for scientific names of plant species used in this report), primarily because the potholes surveyed tended to be both small and shallow. In larger, deeper potholes, common spikerush was the wettest community type, and foxtail barley or western wheatgrass-foxtail barley was intermediate (Figure 20). In the western part of the study area, sloughgrass and Nuttall's alkali grass were generally found with common spikerush. Curlydock (*Rumex crispus*) and knotweed were prevalent in potholes where moisture persisted into late summer.

The western wheatgrass-needle spikerush community type was almost always found in the potholes, even if it was only a narrow ring around the edge of the pothole. We did not see much evidence of salinity in individual potholes, because most do not hold water long enough for evaporation to result in residual salinity. However, there were noticeable salt deposits and salt-tolerant vegetation in some larger basins. Saltbush and western wheatgrass-inland saltgrass were common there (Figure 20).

Figure 19. Western wheatgrass-needle spikerush community

Table 25. Native plant species mentioned in the body of this report

Common Name	Scientific Name	Family
Graminoids		
Blue grama	*Bouteloua gracilis*	Poaceae
Broadleaf cattail	*Typha latifolia*	Typhaceae
Common spikerush	*Eleocharis palustris*	Cyperaceae
Common threesquare	*Schoenoplectus pungens*	Cyperaceae
Foxtail barley	*Hordeum jubatum*	Poaceae
Green needlegrass	*Nassella viridula*	Poaceae
Hardstem bulrush	*Schoenoplectus acutus*	Cyperaceae
Inland saltgrass	*Distichlis spicata*	Poaceae
Needle and thread	*Hesperostipa comata*	Poaceae
Knotweed	*Polygonum* spp.	Polygonaceae
Needle spikerush	*Eleocharis acicularis*	Cyperaceae
Nebraska sedge	*Carex nabracensis*	Cyperaceae
Needleleaf sedge	*Carex duriuscula*	Cyperaceae
Nuttall's alkaligrass	*Puccinellia nuttalliana*	Poaceae
Sloughgrass	*Beckmania syziachne*	Poaceae
Softstem bulrush	*Schoenoplectus tabermontani*	Cyperaceae
Western wheatgrass	*Pascopyrum smithii*	Poaceae
Wheat sedge	*Carex atherodes*	Cyperaceae
Shrubs		
Big sage	*Artemisia tridentata*	Asteraceae
Saltbush	*Atriplex* spp.	Chenopodiaceae

Figure 20. Foxtail barley community

Figure 21. Salt-affected flats

Vegetation in potholes typically varies according to hydrologic regime, and within potholes themselves, the zonation noted above will follow the flooding regime. In the temporarily flooded portions of potholes, typical associations are western wheatgrass-needleleaf sedge, western wheatgrass-needleleaf sedge (-needle spikerush) and western wheatgrass-foxtail barley. In seasonally flooded areas, the more common associations are foxtail barley, foxtail barley-common spikerush(-needleleaf spikerush), common spikerush, needleleaf spikerush, and inland saltgrass-Nuttall's alkaligrass.

The upland vegetation communities surrounding the potholes were predominantly the needle and thread-blue grama community type, although western wheatgrass-green needlegrass community types were frequent in the western part of the study area, especially in moister coulee bottoms and in wet draws. Big sage-blue grama and western wheatgrass-blue grama were sparsely present throughout.

The dominant upland vegetation is best described by the needle and thread-blue grama alliance, a higher classification level in the NVCS. Western wheatgrass-blue grama is a minor upland component. Additionally, one association has been described by the Montana Natural Heritage Program (and proposed for the NVCS) and is found in some potholes: western wheatgrass-(needleleaf sedge). Appendix B contains descriptions of these associations. Although the current global ranking for the western wheatgrass-spikerush spp. type is G1 (Appendix A), this association is now known to be far less rare than it was thought to be when the association was described and the ranking assigned. Thus, we do not consider it to be a community of concern.

In the wet draws draining the Flaxville Gravel formation, sedges were the dominant species (especially Nebraska sedge), with broadleaf cattails. In the wettest sections. Common spikerush dominated the broad coulees below these draws.

Intensive Riparian Assessment

In 2004, we conducted intensive assessments of 17 riparian sites to determine if there was any relationship between site condition and broad-scale watershed assessments. The methodology, described in greater detail in the methods section, involved a probabilistic sampling of vegetation coupled with an evaluation of a suite of disturbance factors (pugging, hummocking, bare ground, bank stability). The vegetation data was analyzed to calculate a variety of metrics, but most notably a floristic quality index (FQI). Earlier work by DeKeyser (2000), Mushet et al. (2002) and Jones (2003) demonstrated the usefulness of a floristic quality index as a metric for evaluating wetland and riparian health. The method is based on assigning coefficients of conservativism (C) to the species occurring in a given region, with values ranging from 0 for non-native species and highly tolerant native invaders to 10 for species with narrow and specific ecological needs, i.e. intolerant species. A site with a high percentage of tolerant species is likely to be disturbed; conversely, a site with a high degree of intolerant species is likely to be free of disturbance. In this study, we used C values set by a panel of experts for native species in the Dakotas (Northern Great Plains Floristic Quality Assessment Panel 2001), and calculated the Floristic Quality Index as:

$$FQI = \overline{C} * \sqrt{n},$$

Where C is the coefficient of conservatism and n is the total number of species. We also calculated the % of non-native species, the total percent of species that are tolerant to disturbance (non-natives, and natives with a C-value of 0, 1, 2, or 3), and the percent of species that are intolerant to disturbance (C-value of 9 or 10). Because we assessed woody vegetation and herbaceous vegetation separately at each site, we analyzed the two types separately. Table 26 shows the results of these calculations. Figures 22 and 23 show the spatial distribution.

None of the sites showed any evidence of hummocking or pugging, although there were signs of cattle presence. Grazing impacts on vegetation were assessed by measuring browse intensity in the quadrats and bare ground in the plots. Although the woody vegetation in 453 of 500 plots showed some signs of browsing, intensity was considered light (no annual segment killed on the stem selected for analysis) in all but 3 of those plots. Within the herbaceous quadrats, bare ground was assessed by counting the number of corners that intersected bare mineral soil. Of the 1190 quadrates, 94 had no intersecting quarters, 221 had 1,434 had 2,344 had 3, and 107 had all four corners intersecting bare ground. However, we found no correlation

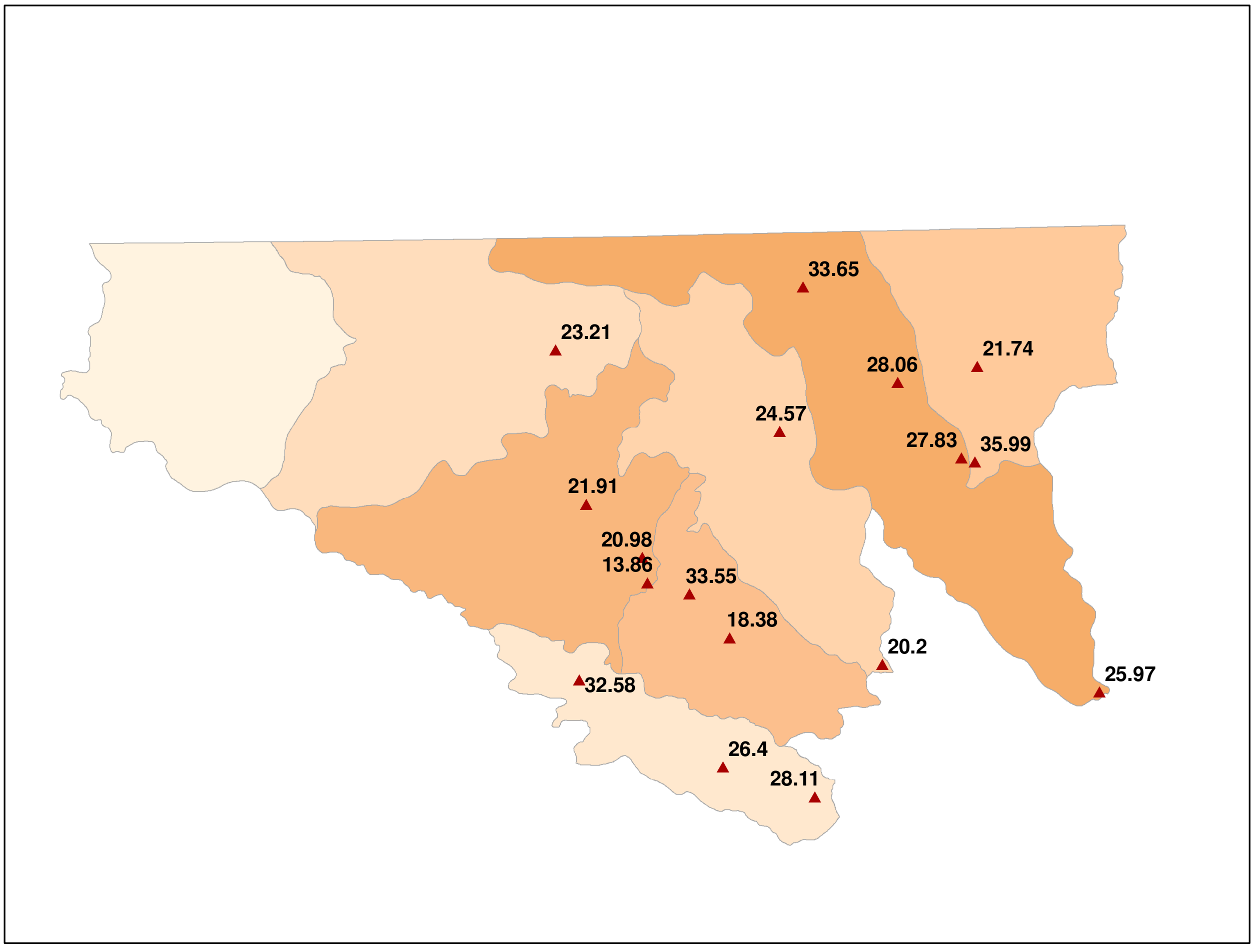


Figure 22. Floristic Quality Index for Herbaceous Plants and % Non-Natives

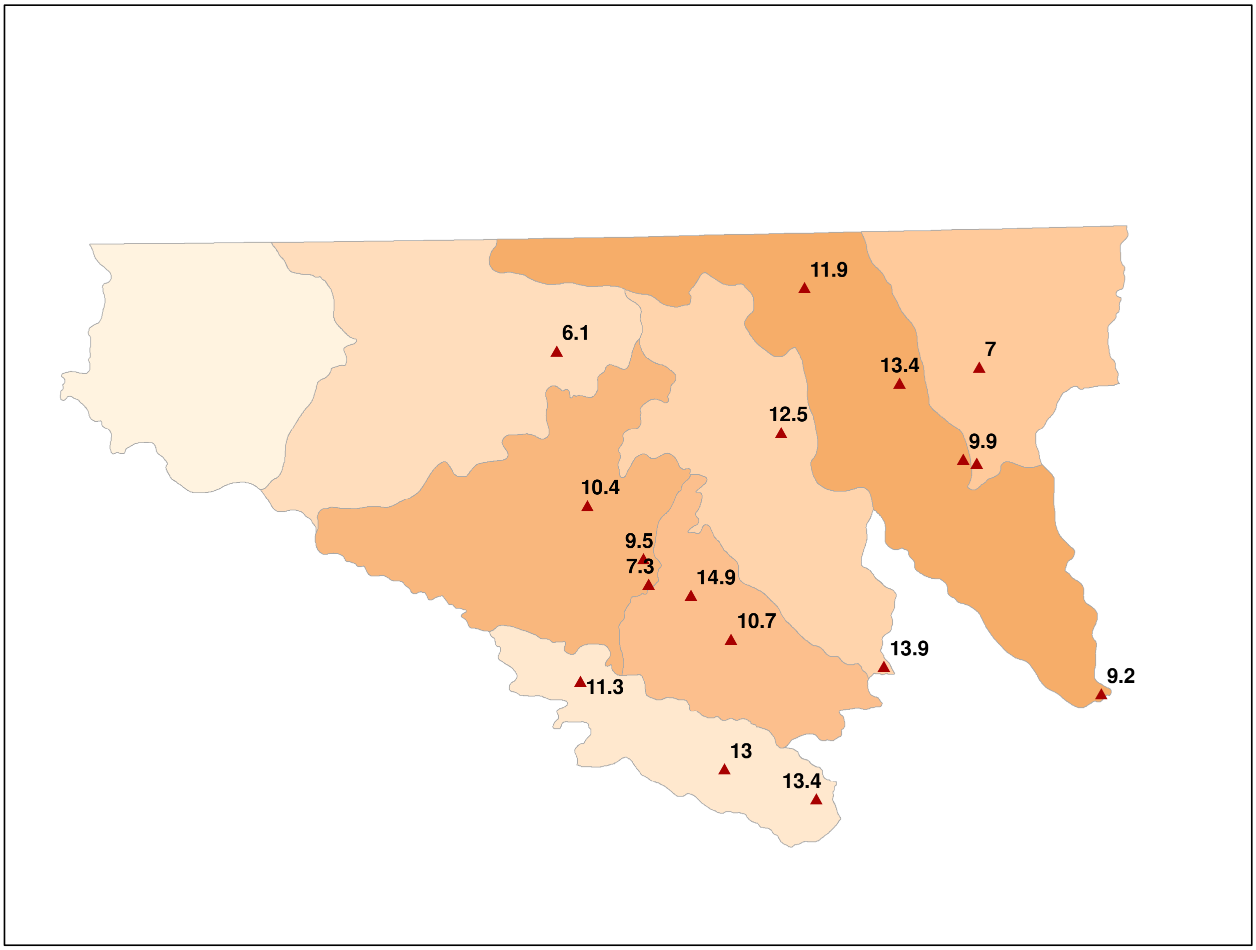


Figure 23. Floristic Quality Index for Woody Plants

between the number of bare corners and any of the other metrics. While the site with the highest percentage of non-native species (Site 1) had one of the highest percentages of bare corners, the same percentage of bare corners was found in Site 461, where the percentage of non-native plants was only 8%. Table 26 also gives the percentage of bare corners by plot.

Almost all sites exhibited a high percentage of tolerant species, with values ranging between 0% and 69.4% for woody species, and from 21.6% to 68.2% for herbaceous species. Non-native herbaceous species were common throughout the riparian area, comprising as many as 46.7% of the individuals at a given site. These non-natives are fairly typical species for areas disturbed by agriculture, and none are considered noxious weeds. Table 27 lists them by scientific and common name. Intolerant species were relatively uncommon in herbaceous plots, and not seen at all in woody plots. The two sites with the highest percentage of intolerant species also had high FQI scores.

Aquatic Condition Inventory

David Stagliano, the Montana Natural Heritage Program Aquatic Ecologist, carried out an aquatic condition inventory in portions of the study as part of a broader project designed to evaluate integrity of BLM managed lands in a watershed context. The goals of his project included identifying and interpreting watershed standards and indicators that could be used to determine aquatic condition. Aquatic communities and riparian areas were inventoried using a combination of methods and protocols (Stagliano 2005).

Table 26. Composition of vegetation in woody (above) and herbaceous(below) categories

Plot ID	1	450	451	455	456	460	461	462	463	464	465	466	467	468	469	470	471
Total species	22.0	72.0	77.0	64.0	29.0	56.0	33.0	62.0	29.0	50.0	30.0	8.0	31.0	31.0	5.0	7.0	40.0
Mean C	5.4	4.7	4.6	4.6	4.1	4.3	4.8	3.6	6.2	5.0	5.1	3.5	5.3	6.7	7.0	7.0	5.6
FQI	10.7	13.4	13.0	13.9	9.2	10.4	9.5	7.3	12.5	14.9	11.3	6.1	11.9	13.4	9.9	7.0	12.4
% Non-natives	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Tolerant species	31.4	38.8	29.0	46.8	58.6	53.6	43.5	69.4	17.2	34.0	23.3	62.5	29.0	3.2	0.0	0.0	10.0
% Intolerant species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Plot ID	1	450	451	455	456	460	461	462	463	464	465	466	467	468	469	470	471
Total species	26.0	41.0	31.0	25.0	37.0	29.0	29.0	13.0	28.0	47.0	46.0	29.0	50.0	38.0	36.0	27.0	53.0
Mean C	4.7	4.4	4.7	4.0	4.3	4.1	3.9	3.8	4.6	4.9	4.8	4.3	4.8	4.6	4.6	4.2	4.9
FQI	23.8	28.1	26.4	20.2	26.0	21.9	21.0	13.9	24.6	33.5	32.6	23.2	33.7	28.1	27.8	21.7	36.0
% Non-natives	46.7	21.0	30.2	7.4	31.0	23.8	8.0	30.5	9.9	11.6	9.0	20.7	3.6	21.2	11.8	21.8	10.7
% Tolerant species	54.4	39.2	40.6	28.3	46.8	38.7	21.6	37.3	33.7	30.2	27.0	28.5	37.8	40.1	50.6	68.2	50.1
% Intolerant species	0.0	0.8	1.0	0.0	1.4	0.9	0.0	0.0	0.3	5.6	3.4	0.7	0.6	1.2	1.8	0.3	5.3
% Bare corners	74.6	25.7	38.2	70.4	41.4	74.3	74.6	67.9	42.1	62.1	37.1	35.0	50.0	59.3	53.6	43.2	58.6

Stream reaches in the 4th-code Cottonwood HUC were delineated into 20 classification codes at the macrohabitat level. In the field, we found that most of the unconnected streams (with a 0 on the end of the HUC code) were dry, and many 2nd order streams contained no water or only interrupted pools. Two broader scale stream types or Aquatic Ecological Systems (Stagliano 2005)) were found within the watershed:

C006 Small perennial prairie streams, origins in the Northwestern Glaciated Plains. Small, low to moderate gradient rivers, at least 30 miles long flowing through alluvium, sedimentary geology class: Cottonwood Creek, 54.1 river miles, Woody Island Coulee 69.4 river miles.

D006 Small intermittent prairie streams, origins in the Northwestern Glaciated Plains. Headwater streams and creeks < 30 miles long with low/mod gradient flowing over sedimentary geology class. Low gradient sections will contain interrupted pools, while medium gradients reaches will be dry: Black Coulee, Murray Coulee, Cowen, Lemere and Coberg Coulee.

The mainstem of Cottonwood Creek, from the confluence of Woody Island Coulee and Black

Figure 24. Cottonwood Creek (site 1-left photo, site 2-right photo) showing G6 channel incisement and unconsolidated, depositional materials at the confluence with Lemere Coulee

Table 27. Non-native species in riparian assessment sites

Scientific Name	Common name
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Alyssum desertorum Stapf	Desert madwort
Bromus inermis Leyss.	Smooth brome
Bromus japonicus Thunb. ex Murr.	Japanese brome
Camelina microcarpa DC.	Littlepod false flax
Chenopodium album L.	Lambsquarters
Chamaesyce glyptosperma (Engelm.) Small	Ribseed sandmat
Chamaesyce serpyllifolia (Pers.) Small	Thymeleaf sandmat
Cirsium arvense (L.) Scop.	Canada thistle
Convolvulus arvensis L.	Field bindweed
Conyza canadensis (L.) Cronq.	Canadian horseweed
Descurainia sophia (L.) Webb ex Prantl	Herb sophia
Elymus repens (L.) Gould	Quackgrass
Euphorbia esula L.	Leafy spurge
Lepidium perfoliatum L.	Clasping pepperweed
Lolium perenne L.	Perennial ryegrass
Medicago lupulina L.	Black medick
Melilotus officinalis (L.) Lam.	Yellow sweetclover
Medicago sativa L.	Alfalfa
Plantago major L.	Common plantain
Poa compressa L.	Canada bluegrass
Polypogon monspeliensis (L.) Desf.	Annual rabbitsfoot grass
Poa pratensis L.	Kentucky bluegrass
Puccinellia distans (Jacq.) Parl.	Weeping alkaligrass
Rumex crispus L.	Curly dock
Sisymbrium altissimum L.	Tall tumblemustard
Sonchus arvensis L.	Field sowthistle
Spergularia maritima (All.) Chiov.	Media sandspurry
Taraxacum officinale G.H. Weber ex Wiggers	Common dandelion
Thlaspi arvense L.	Field pennycress
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	Intermediate wheatgrass
Triticum aestivum L.	Common wheat
Tragopogon dubius Scop.	Yellow salsify
Trifolium repens L.	White clover
Vulpia octoflora (Walt.) Rydb.	Sixweeks fescue

Coulee is an F6-G6 Rosgen channel type (Rosgen 1996). It is severely incised, continually downgrading its channel and forming new depositional material as far as the confluence with the Milk River. With a non-functioning riparian zone (see Figure 24), the stream offers only degraded fish and macroinvertebrate habitat and contains few of the expected fish species for a stream this size (Table 28). There is an immediate loss of species going downstream from the Woody Island Coulee sites to Cottonwood Creek, especially the Iowa darter (*Etheostoma exile*), which prefers weedy, gravel bottoms and clear, cool waters. Cottonwood Creek ranked low in terms of stream integrity when considering the biological community (fish or macroinvertebrates).

By contrast, Woody Island Coulee contained an almost complete assemblage of expected fish species from the Small Perennial Northern Glaciated System (Stagliano 2005). Although only one species of the Northern Redbelly Dace Assemblage #4 (Stagliano 2005) was observed in the watershed, there may be potential to harbor

Table 28. Expected fish assemblages by stream type (Stagliano 2005) and those observed in the Cottonwood Watershed and Assiniboine sub-watershed of the Middle Milk

Aquatic Ecological System	Expected Species Assemblage	Observed Woody Island Coulee Site 1	Observed Woody Island Coulee Site 2	Observed Cottonwood Creek Site 1	Observed Cottonwood Creek Site 2	Observed Assinibione Creek Site 1	Observed Assinibione Creek Site 2
C006 C/W#20 C/W#18	1) fathead minnow 2) white sucker 3) longnose dace 4) lake chub 5) brook stickleback 6) Iowa darter 7) brassy minnow	1) fathead minnow 2) white sucker 4) lake chub 5) brook stickleback 6) Iowa darter 7) brassy minnow	1) fathead minnow 2) white sucker 4) lake chub 5) brook stickleback 6) Iowa darter 7) brassy minnow	1) fathead minnow 2) white sucker 4) lake chub 5) brook stickleback 7) brassy minnow	1) fathead minnow 2) white sucker 4) lake chub	1) fathead minnow 2) white sucker 5) brook stickleback 7) brassy minnow	1) fathead minnow 5) brook stickleback 7) brassy minnow
C006 CW #4	1) Northern Redbelly Dace 2) Northern Redbelly Dace hybrid 3) Pearl Dace	None	1) Northern Redbelly Dace	None	None	1) Northern Redbelly Dace 2) Northern Redbelly Dace hybrid 3) Pearl Dace	1) Northern Redbelly Dace 2) Northern Redbelly Dace hybrid 3) Pearl Dace

Aquatic Ecological System	Expected Species	Observed Black Coulee	Observed Cowen Coulee	Observed Joiner Coulee	Observed Lemere Coulee	Observed Murray Coulee	Observed Garland Creek	Observed Coberg Coulee
D006	1) fathead minnow 2) brook stickleback 3) brassy minnow	1) fathead minnow	1) fathead minnow	1) fathead minnow	1) fathead minnow	1) fathead minnow 2) brook stickleback 3) brassy minnow	1) fathead minnow 2) Northern Redbelly Dace hybrid 3) brassy minnow	1) fathead minnow

others (see Table 28). In particular, we expected to see the Longnose dace (*Rhinichthys cataractae*), which has been reported in riffles in the adjacent tributaries, Battle Creek and Frenchman Creek. Overall, however, Woody Island Coulee had many miles of intact/minimally impacted stream reaches with high biological integrity in both the fish & macroinvertebrate communities.

The full complement of Northern Redbelly Dace Assemblage #4 (Stagliano 2005) assemblage species were found in the Assiniboine Creek sub-watershed, just south of the Cottonwood watershed. This community contains both the Northern redbelly dace (*Phoxinus eos*) and the Pearl dace (*Margariscus margarita*), each a Montana Natural Heritage Program Species of Concern and a BLM sensitive species.

Murray Coulee, a tributary of Woody Island Coulee, was found to have the best potential of the D006 stream types (Table 28) to maintain a fully intact fish community, mostly due to the downstream connection to Woody Island Coulee and a relatively unimpacted 10-mile reach before the confluence.

Garland Creek, a tributary of Cottonwood Creek coming in at river mile 13.4, was identified as having the best potential of the D006 stream types to contain the Northern Redbelly Dace hybrid (*Phoxinus eos x Phoxinus neogaeus*). This unique hybrid was reported in 1979 at the confluence of Garland Creek, but has not been reported again, and may need a revisit to verify further viability in this tributary.

Figure 25 shows the streams referred to in this section with the Composite Watershed Condition Index rating for each 5th-code HUC.

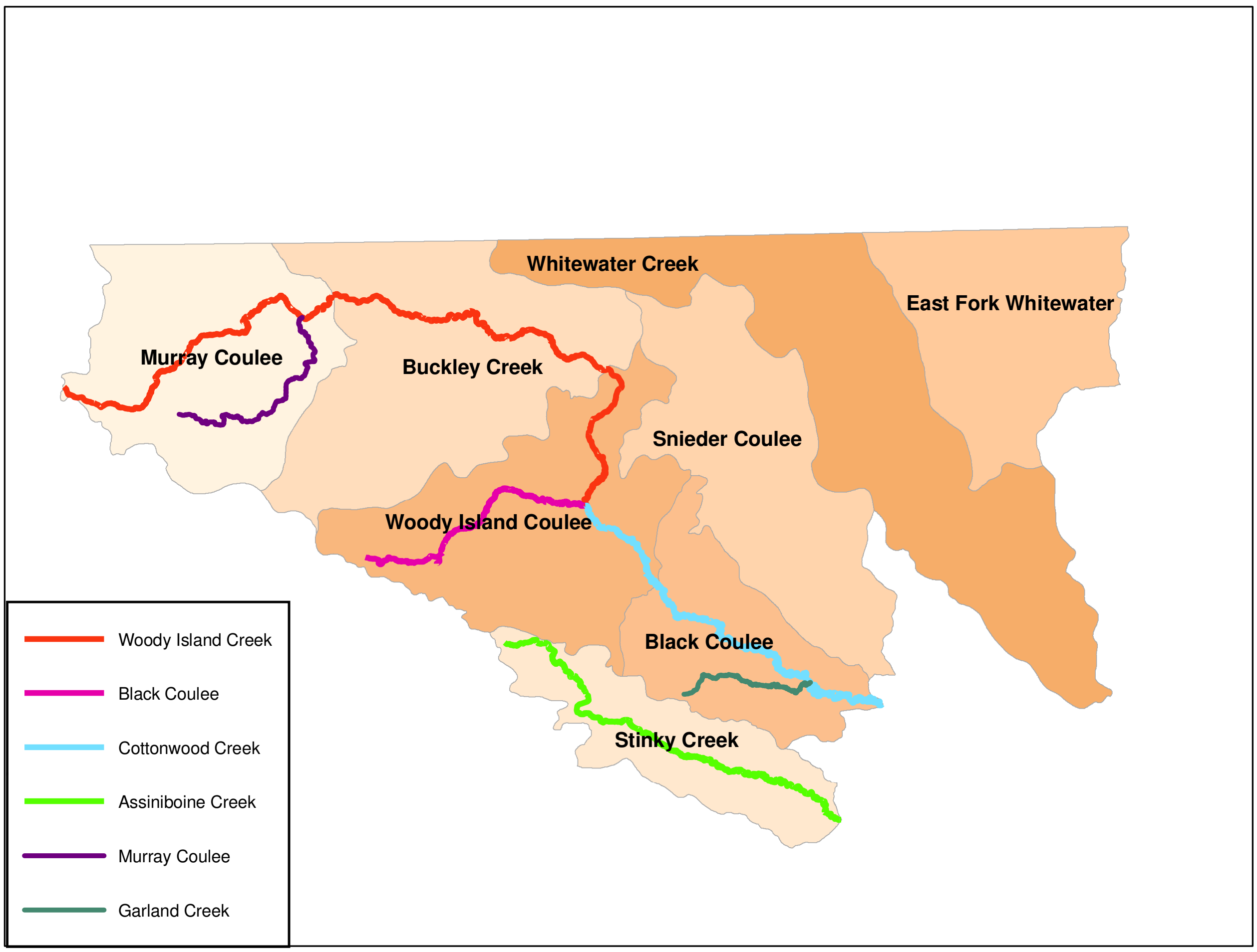


Figure 25. Streams surveyed in Aquatic Condition Inventory

Relationship Between Broad-scale and Fine-scale Assessments

We displayed the results of the PFC assessments, intensive riparian inventory, and aquatic condition inventory on maps of the watershed condition index and visually interpreted the data to determine whether clear correlations exist between broad-scale and fine-scale assessments (Figures 23, 24a and 24b, and 25). While landscape-level factors are known to affect site-level condition, we expected that specific site-level and localized factors (local land cover, management, grazing regimes, etc) would have greater impact on individual site score and species composition than would large-scale factors. As can be seen from the figures, this expectation was verified by the data. The sites in proper functioning condition and in functioning at risk condition are distributed throughout the study area, with no dramatic concentration in any one 5th-code HUC. The same is true for the Floristic Quality Indices (reference); sites with relatively high scores and a low non-native presence are adjacent to sites with low scores and high non-native presence, and do not correspond to overall watershed condition. Results of the aquatic condition inventory probably reflect overall watershed *position* more than individual watershed *condition*; the most degraded reach, the lower Cottonwood, is in a reasonably "healthy" watershed, but its position in the lowest part of the watershed ensures that it will integrate upstream impacts.

The lack of clear relationships between broad-scale and fine-scale assessments can best be understood by distinguishing between cumulative impacts and cumulative effects (Johnson 2005). Broad-scale assessments look at impacts, i.e. the activities and events that change natural conditions, while fine-scale assessments examine the results of those impacts. In the study area, for example, water diversions and impoundments are impacts, while dewatering of streams or loss of species are effects. Impacts may occur at a significance distance from their effects, as is often the case with upstream-downstream relationships observed in aquatic systems, or in close proximity. For plant communities, localized impacts (grazing, agriculture, invasives) may have the most pronounced effects. In our visits to wetlands in the study area, we observed that the most significant effects on plant community composition and proper functioning condition corresponded to highly localized impacts of grazing and/or hydrologic alteration. Individual wetlands with standing water or in the path to standing water were typically trampled, pugged, hummocked, and grazed to near ground level where cattle were present. Broader landscape level impacts were also dwarfed by the local consequences of dredging, excavating or ditching potholes.

Earlier, related studies (Jones 2003) support these observations, suggesting that land use impacts within a buffer zone (<500m) are more likely to have measurable effects on site-level conditions than impacts at a greater distance. However, the value of watershed-level assessments lies in identifying areas where impacts are currently occurring, rather than merely seeking out effects that have already occurred. By combining both site-level and watershed-level assessments, it is possible to select areas where management can make a substantial difference in future wetland and aquatic health. Thus, results of the two levels of assessment needed to be examined less for correlation than for the different perspectives they provide.

Species of Concern

One site for a Montana State Species of Concern, poison suckleya (*Suckleya suckleyana*) was found in the study area during research for the Whitewater Report. This was only the 4th reported occurrence of this plant in the state, and we did not find it any other potholes in the study area. The Montana Natural Heritage Program database lists three other plant Species of Concern in the study area: chaffweed (*Centunculus minimus*), long sheath Waterweed (*Elodea longivaginata*), and dwarf woolyheads (*Psilocarpus brevissimus)* but these were not encountered.

Animal Species of Concern that have been reported in this watershed include: swift fox

(*Vulpes velox*), ferruginous hawk (*Buteo regalis*) western hognose snake (*Heterodon nasicus*), common tern (*Sterna hirundo*), black tern (*Chilidonius niger*) and greater sage grouse (*Centrocercus uropasianus*).

Management Opportunities

The BLM owns and administers a substantial proportion of land within the study area, and can play an important role in conserving or restoring natural functioning. Based on our broad-scale and fine–scale assessments, and our observations in the field, we have identified several specific management opportunities.

Grazing Management

Grazing pressure is substantial throughout the study area. While the number of grazing stock has been reduced in response to ongoing drought, much of the range is heavily utilized. Pothole and riparian vegetation represents an attractive resource for cattle under these circumstances. Even if the drought ceases, potholes with enough ground moisture to support plant growth in late summer will still act as magnets to cattle. Similarly, modification of potholes for stockwatering has been carried out extensively, and these watering holes tend to concentrate both traffic and grazing pressure into specific areas. We recommend that grazing management plans incorporate recognition of the effects of stockwatering areas and the particular vulnerability of potholes to grazing pressures in late summer. Options include:

- Locating stockwatering tanks, nutrient feeders and salt blocks in places with a low concentration of wetlands so that cattle trailing to and from water do not impact adjacent sites.
- Exploration of rotational grazing as a means of protecting breeding waterfowl in early spring and limiting trampling of potholes in late summer.
- Frequent monitoring of utilization in allotments to prevent overuse of upland and wetland resources.
- Increased use of physical barriers to protect high-quality wetland resources. We saw one instance where a high-quality wetland had been fenced off from cattle (Figure 26), and we observed a greater diversity of wetland species and native species in that site than anywhere else in the eastern part of the watershed.

Figure 26. Enclosed wetland

Oil and Gas Development

Oil and gas development is more concentrated in the western part of the study area, but increased demand for the resource is likely to drive further exploration and development through the region. Planning of oil and gas pipelines, and any associated road construction, can take pothole location into account so that direct encroachments are avoided, and impacts from dust, traffic, and erosion are minimized. Many of the drier potholes are not intuitively identified as wetlands in summer months, and construction crews may be oblivious to the smaller and shallower wetlands unless specific efforts are made to locate them.

Invasive Species

The exotic species that were observed in potholes and in riparian areas are not considered noxious, and most are simply agricultural escapees (e.g. smooth brome, crested wheatgrass, Kentucky bluegrass). Nonetheless, the high percentage of non-natives and the extent of bare ground observed in the intensive riparian assessment both indicate that the potential for invasion by noxious weeds is high, should they attain an initial foothold. This region is currently isolated enough from traffic and transient visitors to have resisted colonization by such species as knapweed and leafy spurge, but oil and gas development may facilitate the invasion of noxious weeds as roads are developed and equipment moved between counties and sites. Vigilant monitoring by BLM staff and permittees will be necessary to maintain the weed-free quality of the study area, especially since more populated areas just to the south are experiencing weed problems.

Conservation of Aquatic Resources

Woody Island Creek is a major aquatic resource in the area. The MTNHP aquatic ecologist and wetland ecologist observed fish, amphibians, reptiles, waterfowl, grassland birds and mammals in several locations along the extent of the stream (Figure 27), and concurred that this area warrants continued and focused protection from its headwaters to its confluence with Cottonwood Creek. A similar level of protection is warranted for Assiniboine Creek. Murray Coulee and Garland Creek both require additional monitoring to determine if the species potential is realized there.

Figure 27. Waterfowl in Woody Island Creek

Watershed-specific Management Efforts

The Whitewater Creek and Woody Island Coulee watersheds scored highest on our Composite Watershed Condition index. Both have significant perennial streams, with almost half their acreage under public ownership or management. Whitewater Creek also scored quite high on our Composite Wetland Threat Index. We recommend that these two watersheds be prioritized for conservation planning and restoration efforts. While we do not recommend treating the other watersheds as sacrifice areas, we believe that protecting the healthiest watersheds is a sound management approach. We also note that the watersheds with the lowest scores on the Composite Watershed Condition Index (Murray Coulee, Stinky Creek, Buckley Creek) are the ones with the highest percentage of private ownership. These scores are a reflection of overall land use within the watersheds, and so should not be taken as an indication that public lands within these areas are in any worse condition, or are any less worth of protection, than public lands in other, higher-ranking watersheds. In particular, we reiterate our recommendations that the lands around Woody Island Coulee in the Buckley Creek watershed are a valuable resource, and deserve priority protection.

FUTURE RESEARCH DIRECTIONS

By using broad-scale and fine-scale assessment methods, we were able to characterize and compare 5th-code watersheds across a segment of Montana's Prairie Pothole Region. The assessment provides managers with a substantial body of information that can be used in identifying and acting on management opportunities, and a means of prioritizing action items. However, this study was not exhaustive, and there are several directions future research might take.

Because our main objective was to compare conditions across 5th code watersheds, our GIS-based assessment evaluates impacts without attempting to assign weights to individual stressors. For instance, in our calculation of the Composite Wetland Condition Index, each 5th code HUC received a score between 0 and 1 for the four habitat extent indices (the Natural Cover Index, the Natural Communities Index, the Stream Corridor Integrity Index, and the Lentic Wetland Buffer Index) and the three disturbances indices (the Wetland Direct Disturbance Index, the Diverted Stream Flowage Index, and the Road Disturbance Index). This method implies that the indices carry equal weight, e.g. that the degree of correspondence between expected and observed natural communities has as much significance as the amount of land in natural cover within 100 meters of a wetland, or that the number of diversions and dams per stream mile is an impact equal in importance to the percentage of directly disturbed wetlands. As a tool for comparing wetlands, this methodology is quite acceptable, since all 5th code watersheds are treated in the same way. However, if this approach were being used to assess individual watersheds, it would be useful to carry out a complete literature review and assign weights to wetland stressors that were in proportion to their known effects (Hauer et al. 2000).

The scale of the GIS-based assessment is also open to modification. Here, we used 5th code watersheds as landscape units, but in a more variable area of interest, analyzing 6th-code watersheds might provide a greater degree of detail. We note, too, that this methodology can be used on a much finer scale. Our Composite Wetland Condition Index combines watershed-level and (buffered) wetland-level metrics. If greater agreement between fine-scale and broad-scale assessments is desired, and if the distribution of wetlands across a given area of interest is not so concentrated as in the pothole region, all the metrics can be calculated from conditions within the 100-meter (or other) buffer. This degree of scrutiny is currently being investigated by EPA researchers as part of what is known as the "Level 1,2,3" methodology, which allows users to move between coarse, GIS-based wetland assessments (Level 1) to finer site-based rapid assessments (Level 2) to extremely fine intensive assessments (Level 3) (Whigham et al. 2004).

In similar fashion, the field-based assessment would have greater value if it incorporated a probabilistic sampling plan. In this study, our scope of work called for field-based assessments on an allotment basis, so field sampling points were not randomly distributed across any kind of spatial grid in the study area. Without this kind of random sampling, we can only use the fine-scale assessment data to draw conclusions about the potholes and other wetlands that were actually surveyed, and cannot extrapolate our findings about the percentage of wetlands that are or are not in proper functioning condition to the study area as a whole. In future studies, it would be worthwhile to explore probabilistic sampling as an approach, either on its own or in conjunction with allotment-based sampling, and to investigate the possibility of sampling on private land so that conditions across BLM-managed land could be compared to conditions across the entire area of interest.

Finally, while prairie potholes are a critical and unique resource in the Northern Glaciated Plains region, other wetland types in the study area could be explored in more detail in the future. In particular, alkali lakes in the northeastern part of the study area could be studied in more detail, particularly for their wildlife value. We would especially like to see the wet draws draining from the Flaxville Gravels into the valley bottom of Woody Island Coulee (within the Buckley Creek 5^{th} code HUC) investigated further (Figure 4, above), so that the natural resources there can be fully catalogued. These draws harbor abundant wildlife and considerable plant diversity, but may be receiving chemical inputs from agricultural activities on Big Flat.

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Appendix A. Global/State Rank Definitions

HERITAGE PROGRAM RANKS

The international network of Natural Heritage Programs employs a standardized ranking system to denote global (range-wide) and state status. Species are assigned numeric ranks ranging from 1 to 5, reflecting the relative degree to which they are "at-risk". Rank definitions are given below. A number of factors are considered in assigning ranks — the number, size and distribution of known "occurrences" or populations, population trends (if known), habitat sensitivity, and threat. Factors in a species' life history that make it especially vulnerable are also considered (e.g., dependence on a specific pollinator).

GLOBAL RANK DEFINITIONS (NatureServe 2003)

G1	Critically imperiled because of extreme rarity and/or other factors making it highly vulnerable to extinction
G2	Imperiled because of rarity and/or other factors making it vulnerable to extinction
G3	Vulnerable because of rarity or restricted range and/or other factors, even though it may be abundant at some of its locations
G4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery
G5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery
T1-5	**Infraspecific Taxon** (trinomial) —The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank

STATE RANK DEFINITIONS

S1	At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to extirpation in the state
S2	At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to extirpation in the state
S3	Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas
S4	Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern
S5	Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range

COMBINATION RANKS

G#G# or S#S#	**Range Rank**—A numeric range rank (e.g., G2G3) used to indicate uncertainty about the exact status of a taxon

QUALIFIERS

NR	Not ranked
Q	**Questionable taxonomy that may reduce conservation priority**—Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank

X	**Presumed Extinct**—Species believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered
H	**Possibly Extinct**—Species known from only historical occurrences, but may never-the-less still be extant; further searching needed
U	**Unrankable**—Species currently unrankable due to lack of information or due to substantially conflicting information about status or trends
HYB	**Hybrid**—Entity not ranked because it represents an interspecific hybrid and not a species
?	**Inexact Numeric Rank**—Denotes inexact numeric rank
C	**Captive or Cultivated Only**—Species at present is extant only in captivity or cultivation, or as a reintroduced population not yet established
A	**Accidental**—Species is accidental or casual in Montana, in other words, infrequent and outside usual range. Includes species (usually birds or butterflies) recorded once or only a few times at a location. A few of these species may have bred on the one or two occasions they were recorded
Z	**Zero Occurrences**—Species is present but lacking practical conservation concern in Montana because there are no definable occurrences, although the taxon is native and appears regularly in Montana
P	**Potential**—Potential that species occurs in Montana but no extant or historic occurrences are accepted
R	**Reported**—Species reported in Montana but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program has not yet received first-hand information; others are old, obscure reports
SYN	**Synonym**—Species reported as occurring in Montana, but the Montana Natural Heritage Program does not recognize the taxon; therefore the species is not assigned a rank
*	A rank has been assigned and is under review. Contact the Montana Natural Heritage Program for assigned rank
B	**Breeding**—Rank refers to the breeding population of the species in Montana
N	**Nonbreeding**—Rank refers to the non-breeding population of the species in Montana

APPENDIX B. PLANT ASSOCIATION DESCRIPTIONS

***Carex atherodes* Herbaceous Vegetation**
Awned Sedge Herbaceous Vegetation
Global Rank: G3G5 State Rank: S3S5
Element Code: CEGL002220

ELEMENT CONCEPT

Summary: This awned sedge wet meadow occurs in the northern tallgrass prairie region of the United States and Canada. Stands occur on lowland sites that have standing water for several weeks each year. These sites are typically in depressions or basins but can be along streams and rivers. The water may be fresh or moderately saline. Soils can be mineral but mucks often form through the buildup of organic material. Vegetation cover is usually high but can vary in wet or dry years. Dominant species are herbaceous and typically between 0.5 and 1 m tall. Forb diversity is moderate to high. *Carex atherodes* may form essentially monotypic stands or just be the dominant species. Common associated species include *Alisma triviale, Symphyotrichum lanceolatum (= Aster lanceolatus), Eleocharis palustris, Glyceria grandis* (in drier stands), *Mentha arvensis, Phalaris arundinacea, Polygonum amphibium, Scolochloa festucacea, Sium suave*, and *Sparganium eurycarpum*. Shrubs, including *Salix* spp., can invade this community, especially in the eastern portions of its range.

Comments: See Dix and Smeins (1967) for a discussion of the hydrology of this type, which borders on temporarily vs. seasonally flooded. See also Stewart and Kantrud (1972, including photos on pp. 34-35). Brotherson (1969) performed an ordination of pothole and drainage communities on a prairie in northwestern Iowa and found a community with 55% cover by *Carex atherodes*. The only other species with more than 4% cover was *Polygonum amphibium*, at 30%. *Schoenoplectus fluviatilis (= Scirpus fluviatilis), Calamagrostis canadensis, Carex lasiocarpa, Spartina pectinata*, and *Carex aquatilis* all had between 1 and 3% cover. This community occurred as a narrow band around potholes or sometimes in wide patches.
The relationship of this community and *Scolochloa festucacea* Herbaceous Vegetation needs to better defined. *Carex atherodes* tends to be on non-saline sites while *Scolochloa festucacea* tends to do better on mildly to moderately saline sites (Walker and Coupland 1970). However, the two can co-occur or codominate on mildly saline sites. *Carex atherodes* tends to occur on drier sites (Smith 1973).

ELEMENT DISTRIBUTION

Range: This awned sedge wet meadow occurs in the northern tallgrass prairie region of the United States and Canada, from Minnesota and Iowa, north and west into the Dakotas, Manitoba and perhaps other provinces.

States/Provinces: IA:S?, MB:S2, MN:S?, ND:S?, SD:S?

ELEMENT SOURCES

References: Brotherson 1969, Dix and Smeins 1967, Looman 1982, MNNHP 1993, Smith 1973, Stewart and Kantrud 1971, Stewart and Kantrud 1972, Walker and Coupland 1970

Authors: J. Drake, mod. D. Faber-Langendoen, The Nature Conservancy, Midwestern Conservation Science, Minneapolis, MN **Confidence:** 2

***Distichlis spicata* Herbaceous Vegetation**
Inland Saltgrass Herbaceous Vegetation
Global Rank: G5 State Rank: S4
Element Code: CEGL 001770

ELEMENT CONCEPT

Summary: These grasslands occur in semi-arid and arid western North America from southern Saskatchewan to Mexico. Stands are found in lowland habitats such as playas, swales and terraces along washes that are typically intermittently flooded. The flooding is usually the result of highly localized thunderstorms which can flood one basin and leave the next dry. However, this association may also occur in other flood regimes (temporarily, seasonally, and semipermanently). Soil texture ranges from clay loam to sandy clay. These soils are often deep, saline and alkaline. They generally have an impermeable layer and therefore are poorly drained. When the soil is dry, the surface usually has salt accumulations. Salinity is likely more important than flooding as an environmental factor. Vegetation cover is sparse to dense and is dominated by *Distichlis spicata*, occurring in nearly pure stands. Minor cover of associated graminoids may include *Muhlenbergia asperifolia, Hordeum jubatum, Pascopyrum smithii, Sporobolus airoides, Carex filifolia, Eleocharis palustris, Puccinellia nuttalliana*, and *Juncus balticus*. Associated forbs, such as *Iva axillaris, Helianthus* spp., Asteraceae spp. (from lower salinity sites), *Salicornia rubra, Triglochin maritima*, and *Suaeda* spp., may also be present. Shrubs are rare, but scattered *Atriplex canescens* and *Sarcobatus vermiculatus* may be present.

Comments: This graminoid association is characteristically dominated by *Distichlis spicata*. Closely related communities include *Pascopyrum smithii - Distichlis spicata* Herbaceous Vegetation (CEGL001580), *Sporobolus airoides - Distichlis spicata* Herbaceous Vegetation (CEGL001687), and several others.

ELEMENT DISTRIBUTION

Range: This grassland association occurs in low areas in semi-arid and arid western North America from southern Saskatchewan to Mexico.
S
tates/Provinces: AZ:S3, CA:S3, CO:S3, ID:S4, MT:S4, NM:S4, NV:S?, OR:S4, SK:S?, UT:S3S5, WA:S1?, WY:S3

ELEMENT SOURCES

References: Baker 1984a, Beatley 1976, Bourgeron and Engelking 1994, Brotherson 1987, Bunin 1985, Costello 1944b, Crouch 1961a, Daniels 1911, Daubenmire 1970, Dodd and Coupland 1966, Driscoll et al. 1984, Franklin and Dyrness 1973, Graham 1937, Hansen et al. 1991, Hansen et al. 1995, Hyder et al. 1966, Johnston 1987, Jones and Walford 1995, Kittel and Lederer 1993, Kittel et al. 1994, Kittel et al. 1999a, Klipple and Costello 1960, Muldavin et al. 2000a, Osborn 1974, Ralston 1969, Ramaley 1942, Rogers 1953, Sawyer and Keeler-Wolf 1995, Shanks 1977, Shupe et al. 1986, Soil Conservation Service 1978, Stearns-Roger Inc. 1978, Tuhy and Jensen 1982, Ungar 1967, Ungar 1968, Ungar 1970, Ungar et al. 1969, Vestal 1914, Weaver and Albertson 1956

Authors: K.A. Schulz, THE NATURE CONSERVANCY, WESTERN CONSERVATION SCIENCE, BOULDER, CO **Confidence:** 2

***Eleocharis palustris* Herbaceous Vegetation**

Marsh Spikerush Herbaceous Vegetation

Global Rank: G5 State Rank: S5

Element Code: CEGL 001833

ELEMENT CONCEPT

Summary: This spikerush wet meadow community is found in the central Great Plains of the United States and Canada and in the western United States. Stands occur in small depressions in intermittent streambeds or depression ponds that flood early in the season and may dry out by summer. Stands are composed of submersed and emergent rooted vegetation under 1 m tall that is dominated by *Eleocharis palustris*, often in nearly pure stands. Soils are generally fine-textured.

ELEMENT DISTRIBUTION

Range: This spikerush wet meadow community is found in the central Great Plains of the United States and Canada and in the western United States.

States/Provinces: BC:S4, CA?, CO:S4, ID:S3, MT:S5, NE:S?, NV:SR, OR:S5, SD:S?, SK:S?, UT:S3?, WA:S3?, WY:S3

ELEMENT SOURCES

References: Baker 1983c, Baker and Kennedy 1985, Billings 1945, Bourgeron and Engelking 1994, Brotherson and Barnes 1984, Bunin 1985, Driscoll et al. 1984, Ellis et al. 1979, Flowers 1962, Hall and Hansen 1997, Hansen et al. 1988a, Hansen et al. 1988b, Hansen et al. 1991, Hansen et al. 1995, Kettler and McMullen 1996, Kittel and Lederer 1993, Kittel et al. 1994, Kittel et al. 1999a, Kovalchik 1987, Kovalchik 1993, Mutel 1973, Mutel and Marr 1973, Padgett et al. 1988b, Padgett et al. 1989, Penfound 1953, Ramaley 1919a, Ramaley 1942, Stearns-Roger Inc. 1978, Steinauer and Rolfsmeier 2000, Stewart 1940, Von Loh 2000, Youngblood et al. 1985a

Authors: D. Faber-Langendoen, mod. K. Schulz, mod. M.S. Reid, THE NATURE CONSERVANCY, WESTERN CONSERVATION SCIENCE, BOULDER, CO **Confidence:** 1

***Hesperostipa comata-Bouteloua gracilis* Herbaceous Alliance**
Needle-and-Thread - Blue Grama Herbaceous Alliance
Alliance Code: 1234
V.A. Perennial graminoid vegetation

ALLIANCE CONCEPT

Summary: This alliance is widespread across upland sites in the northern Great Plains. Its communities tend to be the climax communities on fertile dry-mesic sites across much of its range. It is dominated by mid and short grass species; woody species do not regularly achieve prominence. Few of the species exceed 1 m while many, including *Bouteloua gracilis*, do not exceed 50 cm. The most abundant species are *Hesperostipa comata (= Stipa comata)* and *Bouteloua gracilis*. On more mesic sites *Hesperostipa comata* is predominant, while on areas that are drier or subject to light grazing *Bouteloua gracilis* takes precedence. Other graminoid species that are commonly found in communities of this alliance are *Aristida purpurea var. longiseta (= Aristida longiseta), Carex duriuscula (= Carex eleocharis), Carex filifolia, Koeleria macrantha, Nassella viridula*, and *Pascopyrum smithii*. Sites in the southern half of the range of this alliance may have significant amounts of *Bouteloua curtipendula*. Forbs are common but not usually abundant. Forb species that are regularly found are *Artemisia frigida, Gaura coccinea, Gutierrezia sarothrae (= Gutierrezia diversifolia), Liatris punctata, Sphaeralcea coccinea (= Malvastrum coccineum), Phlox hoodii*, and *Sphaeralcea coccinea*. The clubmoss *Selaginella densa* is present in many stands in this alliance. Scattered shrubs are sometimes present. These include *Prunus virginiana, Rhus aromatica*, and *Symphoricarpos occidentalis*. In the western and southwestern portions of its range, *Cercocarpus montanus* may be found where this alliance occurs on slopes.

Communities in this alliance are found on flat to moderately steep topography. The soils are sandy loam, loam, or sometimes clay loam. They are often well-developed and derived from either glacial deposits or sometimes limestone or sandstone (Hanson and Whitman 1938, Coupland 1950, Hanson 1955).

Comments: Communities in this alliance can be confused with communities of the *Bouteloua gracilis* Herbaceous Alliance (A.1282), especially in Wyoming. More classification work is needed to clarify the concept boundaries between stands in this alliances.

ALLIANCE DISTRIBUTION

Range: This alliance is found in the western Great Plains, from western Kansas to North Dakota, west into Colorado, Wyoming and Montana. The alliance also extends north into Canada in Saskatchewan, Manitoba, and probably Alberta.
States/Provinces: AB CO KS MB MT ND NE SD SK WY
Federal Lands: NPS (Badlands?, Fort Laramie, Scotts Bluff, Theodore Roosevelt, Wind Cave); USFWS (Lacreek)

ALLIANCE SOURCE

References: Aldous and Shantz 1924, Badaracco 1971, Bear Creek Uranium Mine Application n.d., Clements and Goldsmith 1924, Comer et al. 1999, Cooper et al. 1995, Cotter-Ferguson Project n.d., Coupland 1950, Coupland 1992a, Davis 1959, DeVelice et al. 1995, FEIS 1998, Faber-Langendoen et al. 1996, Hansen 1985, Hansen and Hoffman 1988, Hansen et al. 1984, Hanson 1955, Hanson 1957, Hanson and Dahl 1956, Hanson and Whitman 1938, Hardy Ranch Mine Application n.d., Hess 1981, Hubbard 1950, Johnston 1987, Kuchler 1964, Laurenroth et al. 1994, Livingston 1947, Moir 1969b, Mueggler and

Stewart 1980, Ramaley 1916b, Smoliak 1965, Smoliak et al. 1972, Soil Conservation Service 1978, Stearns-Roger Inc. 1978, Stoecker-Keammerer Consultants n.d.(a), Tolstead 1941, Tolstead 1942, Trammell and Trammell 1977, Vestal 1914, Weaver and Albertson 1956

Authors: The Nature Conservancy, Midwestern Conservation Science, Minneapolis, MN; Mod. M.S. REID

Hordeum jubatum Herbaceous Vegetation

Foxtail Barley Herbaceous Vegetation
Global Rank: G4 State Rank: S4
Element Code: CEGL 001798

ELEMENT CONCEPT

Summary: This foxtail barley community type is found in the northern and central Great Plains of the United States and Canada, Utah and may occur elsewhere in the interior western U.S. Stands are found in lowlands with moderately to strongly saline soils. The topography is flat and the soils are often flooded or saturated in the spring. The vegetation is dominated by short and medium tall graminoids with a total vegetation cover of nearly 100%. Shrubs are usually absent. *Hordeum jubatum* dominates the community. Other common species in this community are *Elymus trachycaulus, Distichlis spicata, Pascopyrum smithii, Poa arida, Poa compressa*, and *Rumex crispus*.

Comments: This type is poorly defined. This abstract is based on two descriptions of *Hordeum jubatum*-dominated stands which are assumed to be examples of this community. These stands may be variants of *Distichlis spicata - Hordeum jubatum - Puccinellia nuttalliana - Suaeda calceoliformis* Herbaceous Vegetation (CEGL002273) and *Pascopyrum smithii - Hordeum jubatum* Herbaceous Vegetation (CEGL001582). The relationship between *Hordeum jubatum* Herbaceous Vegetation (CEGL001798) and these types is unclear. Both communities usually contain *Hordeum jubatum* and *Distichlis spicata* or *Pascopyrum smithii* in varying amounts. The presence of *Puccinellia nuttalliana* or *Suaeda calceoliformis* may be distinguishing factors. They appear to be more characteristic of strongly saline areas while *Hordeum jubatum* can dominate on less saline sites (Redmann 1972). Classification problems may arise on intermediate sites when *Hordeum jubatum* is the dominant species and *Distichlis spicata, Pascopyrum smithii, Puccinellia nuttalliana*, and *Suaeda calceoliformis* are present in more than minor amounts.

ELEMENT DISTRIBUTION

Range: This foxtail barley community type is found in the northern and central Great Plains of the United States and Canada, ranging from Colorado to Saskatchewan. It is also described from Utah and may occur elsewhere in the interior West.
States/Provinces: CO:S3?, MT:S4, ND:S?, SD?, SK:S?, UT:S?

ELEMENT SOURCES

References: Baker 1984a, Barnes and Tieszen 1978, Bourgeron and Engelking 1994, Bunin 1985, Driscoll et al. 1984, Hansen et al. 1991, Hansen et al. 1995, Jones and Walford 1995, Redmann 1972, Reid 1974, Ungar 1967, Vestal 1914, Von Loh 2000

Authors: J. Drake, mod. K. Schulz, THE NATURE CONSERVANCY, WESTERN CONSERVATION SCIENCE, BOULDER, CO **Confidence:** 3

***Pascopyrum smithii* Herbaceous Vegetation**
Western Wheatgrass Herbaceous Vegetation
Global Rank: G3G5Q State Rank: S4
Element Code: CEGL001577

ELEMENT CONCEPT

Summary: This midgrass prairie type is found in the northern and western Great Plains, Rocky Mountains, and the interior western United States and possibly Canada. Stands occur on level to gently sloping terrain. They are found on alluvial fans, swales, river terraces, floodplains, valley floors and basins. The soils are clay, clay loam, and silt loam. *Pascopyrum smithii* strongly dominates the moderate to dense (40-100% cover) mixedgrass herbaceous canopy that grows 0.5-1 m tall. Other graminoids that co-occur and may achieve local dominance are *Koeleria macrantha, Eleocharis palustris*, and *Poa* spp. Many other species common in midgrass prairies are also found in this community. These include *Artemisia ludoviciana, Eriogonum* spp., *Bouteloua gracilis, Nassella viridula*, and *Hesperostipa comata (= Stipa comata)*. Shrubs and dwarf-shrubs are rare in this community, but occasional woody plants such as *Artemisia tridentata, Symphoricarpos* spp., *Ericameria nauseosa*, or *Krascheninnikovia lanata* may be present. Introduced species, such as *Bromus tectorum, Bromus inermis, Poa pratensis, Melilotus* spp. or *Cirsium arvense*, are common in some stands, especially where disturbed.

Comments: This community is similar to several others that are dominated or codominated by *Pascopyrum smithii*. As currently defined, it represents a western Great Plains and foothills version of the western wheatgrass types in the central Great Plains. Further work needs to be done to refine the differences in composition and environmental characteristics. See recent descriptions by Thilenius et al. (1995) (*Pascopyrum smithii* sodgrass steppe, a more playa-like wheatgrass type) and by Steinauer and Rolfsmeier (2000). In Nebraska, Steinauer and Rolfsmeier (2000) suggest that their stands may resemble *Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation (CEGL001583).

ELEMENT DISTRIBUTION

Range: This midgrass prairie type is found in the northern and western Great Plains, Rocky Mountains, intermountain western United States and possibly Canada, ranging from North Dakota and possibly Saskatchewan, south to Nebraska and Colorado, west to northern Arizona, Utah and Idaho.

States/Provinces: AZ:S?, CO:S1?, ID:S1Q, MT:S4, NE:S?, SD:S?, SK:S?, UT:S3S5, WY:S4Q

Federal Lands: NPS (Fort Laramie, Scotts Bluff, Sunset Crater); USFWS (Ouray)

ELEMENT SOURCE

References: Aldous and Shantz 1924, Baker 1983c, Baker 1984a, Baker and Kennedy 1985, Bourgeron and Engelking 1994, Bunin 1985, Christensen and Welsh 1963, Driscoll et al. 1984, Godfread 1994, Hall and Hansen 1997, Hansen et al. 1991, Hansen et al. 1995, Jones and Walford 1995, Marr and Buckner 1974, Ramaley 1916b, Ramaley 1919b, Ramaley 1942, Shanks 1977, Soil Conservation Service 1978, Steinauer and Rolfsmeier 2000, Thilenius et al. 1995, Thomas et al. 2003c, Von Loh 2000

Authors: J. Drake, mod. K.A. Schulz, The Nature Conservancy, Western Conservation Science, Boulder, CO **Confidence:** 3 **Identifier:** CEGL001577

***Pascopyrum smithii - Bouteloua gracilis* Northern Plains Herbaceous Vegetation**
Western Wheatgrass - Blue Grama Northern Plains Herbaceous Vegetation
Global Rank: G? State Rank: S5?
Element Code: CEGL001578

ELEMENT CONCEPT

Summary: The western wheatgrass - blue grama Herbaceous Vegetation is provisionally identified as a northern Great Plains plant association of hot alluvial settings and thin soil settings overlying shale that are saturated in spring but dry for most of the growing season. It was also found at toeslope and footslope positions that presumably dry quickly following a saturated spring condition. It corresponds with the *Bouteloua-Agropyron* Faciation of Coupland (1960). Western wheatgrass comprises at least 20% cover and blue grama cover can be as much as twice that of western wheatgrass cover. Species diversity is low, and the characteristic forbs include *Opuntia polyacantha* (plains pricklypear), *Linum rigidum* (yellow flax), *Hedeoma hispida* (pennyroyal) and *Sphaeralcea coccinea* (scarlet globemallow). The subshrubs *Gutierrezia sarothrae* (broom snakeweed) and *Artemisia frigida* (fringed sage) are consistently present with low cover (<5%) and a somewhat depauperate form of *Artemisia cana* (silver sagebrush) is also occurs scattered at low densities.

This association was noted to be common in northern Valley County in valleybottom settings of Buggy, South Fork Rock Creek, Crow Creek; presumably it is comparably distributed in drainages of other study area creeks. Heidel et al. (2000), first documented this association for Sheridan County; examples were documented in valleybottom settings along the Big Muddy Creek and in small areas of Sand Creek. It was also found to be locally common on the rolling uplands above alkali lakes. Though the latter is an upland setting, the soils are Ustifluvents.

Classification comments: There is also a *Pascopyrum smithii - Bouteloua gracilis* plant association recognized from foothill and lower-montane valleys of southwestern states. The northern Great Plains examples are treated separately because of non-overlapping climate and setting. However, intervening examples and additional vegetation comparison may link these plant associations that are provisionally treated as distinct. The *Pascopyrum smithii - Bouteloua gracilis* Northern Plains Herbaceous Vegetation plant association grades into the *Pascopyrum smithii - Distichlis spicata* plant association with an increase in salinity (and flooding). It grades into the *Pascopyrum smithii* or *Pascopyrum smithii* - (*Carex duriuscula*) plant associations on sites experiencing intermittent flooding or that are subirrigated early in the growing season . This plant association is typical of the clayey range site. Additional vegetation sampling is needed to document and describe it.

ELEMENT SOURCES

Author(s): Cooper, S. V., C. Jean & B. Heidel, MTNHP **Confidence:** 3
References: Cooper et al. 2001

***Pascopyrum smithii* - (*Carex duriuscula*) Herbaceous Vegetation**
Western Wheatgrass - (Needleleaf Sedge) Herbaceous Vegetation
Global Rank: G? State Rank: S?
Element Code: CEGLMTHP61

ELEMENT CONCEPT

Summary: This small patch association was sampled and observed numerous times within a two county area in north-central Montana. This community is associated with shallow depressions that in "normal" years probably have standing water for a few days to a month or more at the beginning of the growing season, i. e. they are seasonally flooded (Cowardin et al. 1979). This type usually constitutes an encircling, though often discontinuous, vegetation band about these depression and ponds. The dominant visual aspect of a dense rhizomatous grassland is contributed by *Pascopyrum smithii* (western wheatgrass) with a lower layer of much more discontinuous coverage of *Carex duriuscula* (needleleaf sedge).

Environment: This association characteristically occurs in deeper swales and as one of mostly concentric zones around prairie potholes; it was noted only infrequently to be associated with the riparian zone. Because the bulk of these sites were surveyed in the droughty year of 2000 there was no standing water at the time of visitation (even the depression centers often were not flooded) and thus the water regime was difficult to determine. However, old wrack lines and silt deposits were sometimes noted, indicating that flooding had occurred. The soils most often were silt loams, silts, and silty clays. The next wetter zone often is occupied by following herbaceous wetland types, *Pascopyrum smithii - Eleocharis* spp., *Eleocharis palustris* or *Eleocharis acicularis*. Drier positions on this gradient are often characterized as true upland sites with *Elymus lanceolatus - Nassella viridula* (or *Pascopyrum smithii - Nassella viridula*) and *Elymus lanceolatus - Hesperostipa comata* being the dominant vegetation types.

Vegetation: The vegetation is generally species poor, consisting of a thick sward of *Pascopyrum smithii* with a highly variable cover of *Carex duriuscula*. We noted that cattle appeared to preferentially graze the *Carex duriuscula*, even with healthy *Pascopyrum smithii* present. Occasionally these sites had scattered *Distichlis stricta* and *Hordeum jubatum*. The most constant forb was *Aster falcatus*.

Comments: There is a *Pascopyrum smithii* Habitat Type described by Hansen et al. (1995) for Montana that apparently occurs throughout the Intermountain West but neither their description nor their constancy-cover tables allude to the vegetation condition we have encountered in Valley and Phillips Counties. That is, none of these studies describe a co-dominance by *Carex duriuscula* and it is unclear just what landscapes they sampled to arrive at their classification but clearly the *Pascopyrum smithii* plant association from Idaho, Utah, and Washington would not have a Great Plains floristic component as does *Pascopyrum smithii - Carex duriuscula*.

ELEMENT SOURCES

Author(s): Cooper, S. V. and C. Jean, MTNHP **Confidence:** 3
References: Cooper et al. 2001, Hansen et al. (1995)

Pascopyrum smithii - *Eleocharis* spp. Herbaceous Vegetation

Western Wheatgrass - Spikerush species Herbaceous Vegetation

Global Rank: G1 State Rank: S1?

Element Code: CEGL001581

ELEMENT CONCEPT

Summary: This association includes stands of herbaceous vegetation growing in periodically inundated, small playas on the northern Great Plains. The sites supporting this association are closed basins (playas) of <1 ha with fine-textured soils that impede drainage; consequently the playas are flooded periodically. The small basins supporting this association have standing water during "the wet seasons," presumably meaning mainly in the spring and also after heavy summer rains. *Pascopyrum smithii* and *Eleocharis* spp. (*Eleocharis acicularis* or *Eleocharis palustris* or both) dominate the vegetation, and *Hordeum brachyantherum*, *Juncus balticus*, and *Alopecurus* spp. often are present. Stands of this type typically include two zones, resulting from differences in the period of inundation. The lowest part of the stand, which is inundated most often and for the longest time, is dominated by *Eleocharis acicularis*, and may contain *Hordeum brachyantherum*, *Juncus balticus*, and *Alopecurus aequalis* or *Alopecurus carolinianus*, and bare soil accounts for about 75% of the ground surface; the higher part of the stand is dominated by *Pascopyrum smithii* and may contain substantial amounts of *Carex douglasii* and *Vulpia octoflora* var. *octoflora* (= *Festuca octoflora*). The species common in the surrounding vegetation are absent from stands of this type, or contribute little cover.

Vegetation: This type includes low herbaceous vegetation growing in closed basins. *Pascopyrum smithii* and *Eleocharis acicularis* generally dominate, and the plants common in the surrounding steppe generally are absent or contribute very little cover. Stands of this type typically include two zones, resulting from differences in the period of inundation. The following information is from two stands surveyed by Jones (1997): the lowest part of the stand, which is inundated most often and for the longest time, is dominated by *Eleocharis acicularis* and may contain *Hordeum brachyantherum*, *Juncus balticus*, and *Alopecurus aequalis* or *Alopecurus carolinianus*, and bare soil accounts for about 75% of the ground surface; the higher part of the stand is dominated by *Pascopyrum smithii* and may contain substantial amounts of *Carex douglasii* and *Vulpia octoflora* (= *Festuca octoflora*). According to Thilenius et al. (1995), *Hordeum jubatum* occurs on the margins of the stands.

Similar Associations: *Pascopyrum smithii - Hordeum jubatum* Herbaceous Vegetation (CEGL001582)—stands are dominated or co-dominated by *Pascopyrum smithii*, but *Eleocharis acicularis* is absent and *Hordeum jubatum* is a major species. Stands occur in playas where the subsoils contain higher concentrations of sodium (Paris and Paris 1974, Bergman and Marcus 1976). Holpp (1977) described vegetation from 10 playas in Campbell County, Wyoming that seem very similar to the playas containing this association. His stands generally were dominated by *Pascopyrum smithii* and contained some wetland species (*Juncus balticus, Alopecurus carolinianus*), but they showed no consistency in species composition and none contained *Eleocharis acicularis*.

Comments: Species composition varies among stands of this type depending on the degree of inundation, but the degree of variation is unknown. More stand data might indicate that this association and *Pascopyrum smithii - Hordeum jubatum* Herbaceous Vegetation (CEGL001582) should be combined as it also occupies small playas.

ELEMENT DISTRIBUTION

Range: This association has been described from a small area (ca. 250 square miles) in northeastern Wyoming, mainly on the divide between the Belle Fourche River drainage and the Cheyenne River drainage. Two stands apparently have been described from the area of the Montana - South Dakota border as well (Hansen and Hoffman 1988, Table A-5, stands 61 and 136), suggesting that the range of the type may extend into southeastern Montana and western South Dakota. It has been confirmed from northcentral Montana, just south of the Saskatchewan border.

States/Provinces: MT:S1?, SD:S?, SK:S? WY:S1

ELEMENT SOURCES

References: Bergman and Marcus 1976, Bureau of Land Management 1979, Caballo Rojo Mine Application n.d., Hansen and Hoffman 1988, Hansen et al. 1984, Holpp 1977, Jones 1997, Mine Reclamation Consultants 1977, Paris and Paris 1974, Soil Conservation Service 1986, Thilenius et al. 1995, Western Resources Development Corporation n.d.

Authors: G.P. Jones, WCS **Confidence:** 2

***Poa pratensis* - (*Pascopyrum smithii*) Semi-natural Herbaceous Vegetation**
Kentucky Bluegrass - (Western Wheatgrass) Semi-natural Herbaceous Vegetation
Global Rank: GW State Rank: S?
Element Code: CEGL005265

ELEMENT CONCEPT

Summary: This Kentucky bluegrass type is potentially widespread throughout the Great Plains and into the midwestern United States and Canada, depending on how the type is defined. Stands can occur in a wide variety of human-disturbed and native habitats. The vegetation is dominated by medium-tall (0.5-1 m) graminoids. The dominant grass is *Poa pratensis*, considered to be both a native and naturalized species from Eurasia. Other native species may occur as well, but they are generally less than 10% cover. Native species may include mixed-grass prairie grasses, such as *Pascopyrum smithii* and *Hesperostipa comata (= Stipa comata)*, as well as others. Where native species are conspicuous enough to identify the native plant association that could occupy the site, the stand should be typed as such. This type includes only naturalized examples of *Poa pratensis* stands. Maintained lawns are treated as cultural types.

Comments: The debate over whether *Poa pratensis* is either native or introduced appears to be resolved in favor of it being both (Great Plains Flora Association 1986, Gleason and Cronquist 1991). The Great Plains Flora Association (1986) cites Boivin and Love (1960) as the source of this decision. Gleason and Cronquist (1991) state that in most parts of their Manual's range (Northeast and Midwest United States and adjacent Canada), the species is introduced, but that it is probably native along their northern boundary and in Canada.

This type could be narrowly restricted to mixed-grass prairie stands where *Poa pratensis* dominates to the exclusion of most other species, or it could be expanded to include almost any naturalized stand dominated by *Poa pratensis*. Where native species are conspicuous enough to identify the native plant association that could occupy the site, the stand should be typed as such. This type includes only naturalized examples of *Poa pratensis* stands. Maintained lawns are treated as cultural types.

ELEMENT DISTRIBUTION

Range: This Kentucky bluegrass type is potentially widespread throughout the Great Plains and into the midwestern United States and Canada.

States/Provinces: MT:S?, ND:S?, SD:S?, WY:S?

Federal Lands: NPS (Badlands, Theodore Roosevelt, Wind Cave); USFWS (Lacreek)

ELEMENT SOURCES

References: Gleason and Cronquist 1991, Great Plains Flora Association 1986

Authors: D. Faber-Langendoen, MCS **Confidence:** 3 **Identifier:** CEGL005265

Puccinellia nuttalliana Herbaceous Vegetation

Nuttall's Alkali Grass Herbaceous Vegetation
Global Rank: G3? State Rank: S?
Element Code: CEGL 001799

ELEMENT CONCEPT

Summary: This wetland association is described from a high-elevation (2900 m) park in central Colorado and in southwestern and central Montana, but likely occurs elsewhere across the western and northern Great Plains and the western U.S. and Canada. While the dominant species occurs over a broad geographic range, it has quite specific habitat needs requiring moist soils of intermediate salinity in seasonally wet meadow habitats. Site topography is generally flat with poor drainage. In South Park, Colorado, there is often a small microtopography of hummocks which affects the water relations and therefore species composition. The soils are moist, saline and alkaline, derived from calcareous shales. The snow/rain- and groundwater-saturated soils usually dry out during the growing season. Communities form a ring just above the succulent plant associations associated with playas, salt flats and saline lakes, or may occur as patches along intermittent drainages. They exist in saline soils that range from 0.7-1% total salts. The pH levels are commonly very alkaline. The wetland vegetation is characterized by the dominance of *Puccinellia nuttalliana* in the graminoid layer. *Distichlis spicata* or *Hordeum jubatum* may codominate is some stands. The forb layer is relatively sparse and is often composed of *Salicornia rubra* or *Triglochin maritima*. Diagnostic of this herbaceous wetland association is the dominance of *Puccinellia nuttalliana*.

ELEMENT DISTRIBUTION

Range: This association occurs on moist soils of intermediate salinity in seasonally wet meadow habitats of South Park, Colorado (Ungar 1974c). Possible stands of this association have been noted by researchers in the eastern (Nebraska) and northern plains regions to Saskatchewan and through the intermountain region to Utah and California (Ungar 1974c).

States/Provinces: CO:S1?, MT:S?, NV?, SD?, SK?, UT?

ELEMENT SOURCES

References: Bourgeron and Engelking 1994, Cooper et al. 1999, Dodd and Coupland 1966, Driscoll et al. 1984, Gersib and Steinauer 1991, Ungar 1970, Ungar 1972, Ungar 1974c, Young et al. 1986

Authors: D. Sarr, THE NATURE CONSERVANCY, WESTERN CONSERVATION SCIENCE, BOULDER, CO **Confidence:** 2

Schoenoplectus acutus Herbaceous Vegetation

Hardstem Bulrush Herbaceous Vegetation

Global Rank: G5 State Rank: S5

Element Code: CEGL001840

ELEMENT CONCEPT

Summary: This association is a common emergent herbaceous wetland found mostly in the interior western U.S. ranging from the Puget Sound of Washington to Montana south to California, Nevada and Utah. Stands occur along low-gradient, meandering, usually perennial streams, river floodplain basins, and around the margins of ponds and shallow lakes especially in backwater areas. Some sites are flooded most of the year with about 1 m of fresh to somewhat saline or alkaline water. Other sites, however, dry up enough in late summer to where the water table drops below the ground surface, though the soils are still partially saturated. Soils are generally deep, organic, alkaline, poorly drained and fine-textured, but range in soil textures from sand to clay to organic muck. The soils may be normal or saline. Vegetation is characterized by a dense tall herbaceous vegetation layer 1-3 m tall that is dominated by *Schoenoplectus acutus (= Scirpus acutus)*, often occurring as a near monoculture. Associated species include low cover of *Mentha arvensis, Polygonum amphibium, Sagittaria latifolia*, and species of *Carex, Eleocharis, Rumex*, and *Typha*. Early in the growing season or at permanently flooded sites, aquatic species such as *Potamogeton* spp. and *Lemna minor* may be present to abundant. Stands of this association contain no tree or shrub layer, but a few sites have been invaded by the introduced shrub *Tamarix* spp.

Comments: This association appears to be somewhat variable in flood regime. It is flooded less time than some of the other *Schoenoplectus acutus* associations in this semipermanently flooded alliance with some stands included in this association occurring in a seasonally flooded hydrologic regime. However, stands described by Kunze (1994) from western Washington were permanently flooded with shallow water (about 1 m deep). Additional research is needed to determine if the different hydrological regimes indicate a need to split out new associations.

ELEMENT DISTRIBUTION

Range: This association is a common emergent wetland found mostly in the interior western U.S. from Washington to Montana south to California, Nevada and Utah.

States/Provinces: CA:S3?, ID:S4, MT:S5, NV:S?, OR:S5, UT:S?, WA:S4

TNC Ecoregions: 10:C, 11:C, 17:C, 2:C, 6:C

ELEMENT SOURCES

References: Bourgeron and Engelking 1994, Bundy et al. 1996, Dethier 1990, Driscoll et al. 1984, Evans 1989a, Hansen et al. 1991, Hansen et al. 1995, Kunze 1994

Authors: K.A. Schulz, THE NATURE CONSERVANCY, WESTERN CONSERVATION SCIENCE, BOULDER, CO **Confidence:** 1

Northern Prairie Pothole Wetland Complex
Global Rank: G3G5 State Rank: ?
Element Code: CECX005705

ELEMENT CONCEPT

Summary: Northern prairie wetland complexes occur widely throughout the glaciated northern Great Plains of the United States and Canada. They are responsible for a significant percentage of the annual production of many economically important waterfowl in North America. Prairie potholes are mostly closed basins that receive irregular inputs of water from their surroundings (groundwater and precipitation), and export water as groundwater. Climate of the region is characterized by mid-continent temperature and precipitation extremes, with areas in the region having summer highs of over 38 degrees C and winter lows below -40 degrees C. Precipitation ranges from over 56 cm in the southeast to barely 25 cm along the western edge of the region. The prairie pothole region is covered by a thin mantle of glacial drift overlying stratified sedimentary rocks of Mesozoic and Cenozoic ages. Hydrology of the potholes is complex. Precipitation and runoff from snowmelt are often the principal water sources, with groundwater inflow secondary. Evapotranspiration is the major water loss, with seepage loss secondary. Most of the wetlands and lakes contain water that is alkaline (pH >7.4). The concentration of dissolved solids in these waters ranges from fresh to extremely saline. On the basis of phosphorus supply and concentration of phosphorus, many of these wetlands are eutrophic. Chemical characteristics, especially of the larger ponds (>5 ha) and lakes, vary both seasonally and annually. Because surface water chemistry can change dramatically in prairie lakes and wetlands, it can be difficult to classify a body of water into a particular salinity type. The flora and vegetation of a prairie wetland is a function of the water regime, salinity, and disturbance by humans. Within a pothole, water depth and duration determines the local gradient of species. Potholes deep enough to have standing water, even during droughts, will have a central zone of submersed aquatics (open water). In wetlands that go dry during periods of drought or annually, the central zone will be dominated by either tall emergents (deep marsh) or mid-height emergents (shallow marsh), respectively. Potholes that are only flooded briefly in the spring are dominated by grasses, sedges, and forbs (wet meadow). A distinct drawdown zone will also occur. The depth of the deepest part of the pothole and the relative steepness of the local relief will determine how many zones occur in a given pothole. These patterns are impacted by the extent of drainage, grazing, mowing, and burning occurring in the pothole, and by sedimentation, nutrient runoff, and pesticides from adjacent plowing. In addition, because of periodic droughts and wet periods, many wetlands undergo vegetation cycles.
The combination of vegetation cycles and diffuse zonation patterns makes classification of prairie pothole wetlands difficult. The prairie pothole complex proposed here is an alternative means of applying the U.S. National Vegetation Classification (USNVC) to prairie potholes. The complex is still a preliminary idea and could take several approaches, based on ecoregional and water chemistry patterns. Regardless of the approach chosen, it should still be possible to describe the characteristic vegetation of the complex using the USNVC associations.

Environment: Prairie potholes are mostly closed basins that receive irregular inputs of water from their surroundings, and export water as groundwater. Climate of the region is characterized by mid-continent temperature and precipitation extremes, with areas in the region having summer highs of over 38 degrees C and winter lows below -40 degrees C. Precipitation ranges from over 56 cm in the southeast to barely 25 cm along the western edge of the region. Wetlands typically fill in the spring, when snowmelt runs off the frozen soil. The prairie pothole region is covered by a thin mantle of glacial drift overlying stratified sedimentary rocks of Mesozoic and Cenozoic ages. The rocks consist primarily of limestones, sandstones, and shales. Highly mineralized water can discharge upward from these sedimentary rocks into the glacial drift. The geomorphology of the drift consists of end moraines, stagnation moraines, ground moraines, outwash plains, and lakeplains. The drift is thickest in areas of end and stagnation moraines, generally 60 to 120 m. In areas of ground moraines and lakeplains, the drift is generally less than 30 m thick. The drift is generally fine-grained, silty and clayey soils. The end and stagnation moraines can rise up from 10 to greater than 100 m above the surrounding flatter plains, creating relatively steep local relief. On other drift, the land slopes are slight, and local relief may only be a few meters (Winter 1989).

Hydrology of the potholes is complex. The generally low land surface relief results in low runoff velocities. Numerous small depressions in morainal areas are not part of an integrated drainage system, and contribute little to stream flow. Finally, because the geological materials have low permeability, infiltration also is minimal. Infiltration is further limited because climatic conditions are such that soil frosts are usually deep (1 to 1.3 m), causing spring snowmelt to run off into the potholes until they would overflow from one pothole to the next. Groundwater recharge and discharge can lead to areas of seepage, as topographically high wetlands discharge into adjacent lower areas. This can lead, e.g., to freshwater springs discharging into saline lakes. Both the spring melt and groundwater phenomenon illustrate how pothole hydrology is best studied when the wetlands complexes are treated as interconnected hydrologic units (Winter 1989).

Precipitation and runoff from snowmelt are often the principal water sources, with groundwater inflow secondary with about 15% of total inflow. Evapotranspiration is the major water loss, with seepage loss only about 15-20% of total outflow (Winter 1989).

Most of the wetlands and lakes contain water that is alkaline (pH >7.4), and pH values of 10.8 have been reported. The concentration of dissolved solids in these waters ranges from fresh to extremely saline. Calcium, magnesium, sodium, and potassium have each been determined to be the most abundant cations in these prairie wetlands, and bicarbonate, sulfate, and chloride the most abundant anions. The least saline waters commonly are a calcium bicarbonate type, and the most saline waters commonly are a sodium sulfate type. However, water type and salinity are independent. On the basis of phosphorus supply and concentration of phosphorus, many of these wetlands are eutrophic (Labaugh 1989).

Chemical characteristics vary both seasonally and annually, especially in larger potholes (>5 ha). Seasonal variation in major ions is affected by concentration under ice cover, dilution due to snowmelt and runoff, concentration by evaporation, dilution from rainfall, and interaction with groundwater. A variety of classifications exist in the literature with respect to salinity. The most widely used in the U.S. was that of Stewart and Kantrud (1972), who based their scale on the correlation between distinctly different plant communities and the relative concentrations of dissolved solids, indicated by specific conductance. Their categories were fresh (<500 uS/cm), slightly brackish (500-2000 uS/cm), moderately brackish (2000-5000 uS/cm), brackish (5000-15,000 uS/cm), subsaline (15,000-45,000 uS/cm), and saline (>45,000 uS/cm). Millar (1976) used a similar approach in western Canada, but defined four categories: fresh (<1400 ppm or <2000 uS/cm), moderately saline (1400-10,500 ppm), saline (10,500-31,500 ppm) and hypersaline (>31,500 ppm). Numerous wetlands and lakes in the northern prairies are more saline than the ocean (approximately 50,000 uS/cm). Because surface water chemistry can change dramatically in prairie lakes and wetlands, it can be difficult to classify a body of water into a particular salinity type (Labaugh 1989).

Vegetation: The flora of a prairie wetland is a function of the water regime, salinity, and disturbance by humans. Within a pothole, water depth and duration determine the local gradient of species. Potholes deep enough to have standing water, even during droughts, will have a central zone of submersed aquatics (open water). In wetlands that go dry during periods of drought, or annually, the central zone will be dominated by either tall emergents (deep marsh) or mid-height emergents (shallow marsh), respectively. Potholes that are only flooded briefly in the spring are dominated by grasses, sedges, and forbs (wet meadow). The depth of the deepest part of the pothole and the relative steepness of the local relief will determine how many zones occur in a given pothole. These patterns are impacted by the extent of drainage, grazing, mowing, and burning occurring in the pothole, and by sedimentation, nutrient runoff, and pesticides from adjacent plowing (Kantrud et al. 1989).

Because of periodic droughts and wet periods, many wetlands undergo vegetation cycles. Periods of

above normal precipitation can raise water levels high enough to drown out emergent vegetation or produce "eat outs" due to increases in the size of muskrat populations that accompany periods of high water (Kantrud et al. 1989). The elimination of emergents creates an open-water marsh, dominated by submerged aquatics. During the next drought when the marsh bottom is exposed by receding water levels (a drawdown), seeds of emergents and mudflat annuals in the soil seed bank germinate (dry marsh). When the marsh refloods, the emergents survive and spread vegetatively (Kantrud et al. 1989).
Zonation patterns are conspicuous in prairie potholes, because each zone often is dominated by a single species that has a lifeform different from those in adjacent zones. But each zone is constantly adjusting to the shifting environmental gradients within the pothole, which can create a lag in response among various species, and cloud the compositional patterns within the zones (Kantrud et al. 1989, Johnson et al. 1987). The combination of vegetation cycles and clouded zonation patterns makes classification of prairie pothole wetlands difficult.

Dynamics: Floods can occur during spring melt, because soil frosts are usually deep (1-1.3 m). This causes the spring snowmelt to run off into the potholes until they overflow prominent potholes (Winter 1989). Because of periodic droughts and wet periods, many prairie wetlands undergo vegetation cycles. Periods of above normal precipitation can raise water levels high enough to drown out emergent vegetation or cause them to be eaten out by muskrat populations that increase during periods of high water (Kantrud et al. 1989). Wave action can also cause disturbances of the shoreline vegetation. During the next drought when the marsh bottom is exposed by receding water levels (a drawdown), seeds of emergents and mudflat annuals in the soil seedbank germinate (dry marsh). When the marsh refloods, the emergents survive and spread vegetatively (Kantrud et al. 1989).
The drawdown zone is particularly dynamic. Vegetation tends to be more sparse around permanent ponds and more dense in temporary ponds. The zone is typically inundated early in the season, but is generally dry by late spring or early summer. The vegetation is often very diverse, since drawdowns happen to varying degrees from year to year.
Prairie fires could also be expected to sweep through these wetlands, particularly during drawdown periods.

GRank & Reasons: G3G5 (00-01-31). This rank has been assigned based on the widespread distribution of the complex, the commonness of many of the component associations, and the high rank of a few associations. Thus individual potholes typically do not contain rare vegetation types, but some may. Many potholes are small, landscapes have been extensively ditched for drainage, and farming and ranching activities can lead to plowing, high levels of nutrient run-off and siltation, or heavy grazing.

Comments: The complex proposed here is an alternative to applying the USNVC to prairie pothole wetlands. The USNVC, like that of the national wetland classification (Cowardin et al. 1979), in principal classifies each zone as a separate association or wetland type, respectively. By contrast, Stewart and Kantrud (1972) developed a classification system of prairie potholes that recognized different phases of vegetation zones dominated by the major lifeforms in each, from open water to wet meadow. They also used the composition of the zone as an indicator of the water regime, water chemistry and disturbance. Each pothole was assigned to a type based on the deepest part (zone).
The prairie pothole complex proposed here relies in part on the method of Stewart and Kantrud (1972). The complex is still a preliminary idea, and could take several approaches. First, the complex could be treated most broadly as a single unit, putting all wetlands across the entire region into a single unit. Second, the complex could be subdivided into major subregions. Three possibilities, suggested by D. Ode (pers. comm. 1999) are: (1) Tallgrass Prairie/Aspen Parkland Region (Province 251), where a higher proportion of open water and deep emergent marshes with fresh water chemistry occur; (2) James Basin and Missouri Coteau Region (Province 332), where the vast majority of wetlands are shallow marsh and wet

meadow types; and (3) Northwestern Region (Province 331), where brackish and saline types predominate. Finer divisions at section or subsection levels would also be possible and have been used in Alberta (L. Allen pers. comm. 1999).

Third, the complex could be defined based on the deepest zone within a complex, following Steward and Kantrud (1972). There would be the following subtypes: (1a) open marsh, freshwater complex; (1b) open marsh, brackish/saline complex; (2a) deep marsh, freshwater complex; (2b) deep marsh, brackish/saline complex; (3a) shallow marsh, freshwater complex; (3b) shallow marsh, brackish/saline complex; (4a) wet meadow, freshwater complex; (4b) wet meadow, brackish/saline complex; (5a) fens/seeps, freshwater complex; (5b) fens/seeps, brackish/saline complex; (6a) drawdown, freshwater complex; (6b) drawdown brackish/saline complex. Individual associations found within each of these complexes would then be listed (see below). Any combination of these options is also possible. Regardless of the approach taken, a complete list of associations found within a given complex can be developed, and a first start at a comprehensive list across the entire range of complexes is provided below, categorized by Steward and Kantrud's categories.

Sandhill prairie wetlands in northwestern Nebraska could be considered another kind of prairie pothole wetland complex. They are not glaciated and are located in areas of sand dunes. Northern glaciated prairie lakes (approximately >8 ha or 20 acres in size, and over 2 m deep using Cowardin et al. 1979 criteria) are not included in this wetland complex.

ELEMENT DISTRIBUTION

Range: This complex occurs widely throughout the glaciated northern Great Plains of the United States and Canada. The range can be approximated by referring to Bailey's (1994) U.S. Ecoregional Section map. It covers the northern parts of Provinces 251 (251A?,251B), 332 (332A,332B,332D), and 331 (331D, 331E) in western Minnesota, eastern South Dakota and North Dakota, and extreme northern Montana, as well their equivalents in southwestern Manitoba, southern Saskatchewan and southeastern Alberta (see Bailey 1997).

Nations: CA US

States/Provinces: AB:S?, MB:S?, MT:S?, ND:S?, NE?, SD:S?, SK:S?, WY:S?

ELEMENT SOURCES

References: Johnson et al. 1987, Kantrud et al. 1989, Labaugh 1989, Millar 1976, Stewart and Kantrud 1972, Winter 1989

Authors: D. Faber-Langendoen, MCS **Confidence:** 2 **Identifier:**

Appendix C. Additional Reference Tables

Table 1. Wetland habitat classification levels from the U.S. Fish and Wildlife Service's National Wetland Inventory system (Cowardin et al. 1979) that are most applicable to the prairie potholes in the study area

Taxon	Definition
Systems and Subsystems	
Palustrine (P)(System)	Persistent emergents (herbaceous plants), trees, shrubs and/or emergent mosses cover more than 30% of the area
Lacustrine (L) (System)	Inland water body; situated in a basin; catchment or on level or sloping ground; >8 acres in area; >2 ft. in depth and/or with wave-formed shoreline; water usually not flowing
Littoral (2) (Subsystem)	The wetland habitat of the Lacustrine system dominated by nonpersistent emergents (herbaceous plants rooted in the lakebed)
Riverine (R) (System)	Inland water body; situated in a channel; water usually flowing
Intermittent (4) (Subsystem)	Channel contains flowing water for only part of the year
Lower Perennial (2) (Subsystem)	Channel contains water throughout the year; gradient is low and water velocity is slow
Classes within the above Systems and Subsystems	
Aquatic Bed (AB)	Dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years
Emergent (EM)	Dominated by erect, rooted herbaceous hydrophytes
Scrub-Shrub (SS)	Dominated by woody vegetation less than 6m in height
Forested (FO)	Dominated by woody vegetation greater than 6 m in height
Unconsolidated Bottom (UB)	At least 25% cover of particles smaller than stone; less than 30% vegetative cover
Unconsolidated Shore (US)	Less than 25% cover of stones, boulders and/or bedrock; less than 30% vegetative cover
Streambed (SB)	Exposed when intermittent stream is running no water
Water Regime Modifiers	
Intermittently Exposed (G)	Surface water is present throughout the yar except in years of extreme drought
Semipermanently Flooded(F)	Surface water persists throughout the growing season in most years; when surface water is absent, the water table is usually at or very near the land surface
Seasonally Flooded (C)	Surface water is present for extended periods especially early in the growing season, but is absent by the end of the season in most years; when the surface water is absent, the water table is often near the land surface
Temporarily Flooded (A)	Surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface for most of the season
Special Modifiers (denoting hydrological modification)	
Excavated (x)	Wetland lies within a basin or channel excavated by humans

Table 1. Continued

Taxon	Definition
Special Modifiers (denoting hydrological modification)	
Excavated (x)	Wetland lies within a basin or channel excavated by humans
Impounded/Diked (h)	Wetland created or modified by a barrier or dam that purposely or unintentionally obstructs the outflow of water; created by humans or beavers; wetland created or modified by a human-made barrier or dike designed to obstruct the inflow of water
Partly Drained/Ditched (d)	The water level has been artificially lowered

Table 2. Wetland habitat classification levels from Classification of Natural Ponds and Lakes in the Glaciated Prairie Region (Stewart and Kantrud 1971) most applicable to the prairie potholes in the Whitewater watershed

Taxon	**Definition**
Vegetation Zones	
Wetland low-prairie	Surface water ordinarily maintained for only a brief period in the early spring
Wet meadow	Surface water usually maintained for only a few weeks after the spring snowmelt and occasionally for several days after heavy rainstorms
Shallow-marsh emergent	Surface water maintained for an extended period in spring and early summer but frequently gone during late summer and fall
Deep-marsh emergent	Surface water maintained throughout the spring and summer and frequently maintained into fall and winter
Permanent open water	Self-explanatory
Hydrologic Phases	
Normal emergent phase	Plant growth extends above the water surface
Open water phase	No plants or plant growth beneath water surface
Natural drawdown emergent phase	Plants germinate on bare soil after surface water recedes
*Salinity Subclasses**	
Fresh	<40-500 micromhos/cm3 conductance
Slightly brackish	500-2,000 micromhos/cm3 conductance
Moderately brackish	2,000-5,000 micromhos/cm3 conductance
Subsaline	5,000-15,000 micromhos/cm3 conductance

*Because conductance can fluctuate greatly in a wetland, plant species occurrences are used as indicators of the salinity of the vegetation zone.